This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

**Usage guidelines**

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

**About Google Book Search**

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Gj-A 512.95 E

WHITNEY LIBRARY,

HARVARD UNIVERSITY.

THE GIFT OF

J. D. WHITNEY,

*Sturgis Hooper Professor*

IN THE

MUSEUM OF COMPARATIVE ZOÖLOGY

6988

January 30, 1902

TRANSFERRED TO GEOLOGICAL SCIENCES LIBRARY

# TRANSACTIONS

OF THE

# AMERICAN INSTITUTE OF MINING ENGINEERS.

## VOL. XIV.

JUNE, 1885, TO MAY, 1886.

HARVARD GEOLOGY LIBRARY

NEW YORK CITY:
PUBLISHED BY THE INSTITUTE,
AT THE OFFICE OF THE SECRETARY.

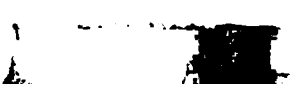
© 1886.

J. D. WHITNEY.

HARVARD UNIVERSITY.

WHITNEY LIBRARY,

MUSEUM OF COMPARATIVE ZOÖLOGY.



# TRANSACTIONS

OF THE

# AMERICAN INSTITUTE OF MINING ENGINEERS.

## VOL. XIV.

---

JUNE, 1885, TO MAY, 1886.

---

NEW YORK CITY:
PUBLISHED BY THE INSTITUTE,
AT THE OFFICE OF THE SECRETARY.
1886.

PHILADELPHIA:
SHERMAN & CO., PRINTERS.

# CONTENTS.


| | PAGE |
|---|---|
| PROCEEDINGS OF THE XLIId MEETING, CHATTANOOGA, May, 1885, | 1 |
| PAPERS OF THE CHATTANOOGA MEETING, May, 1885, | 17 |
| The Relative Value of Coals to the Consumer. By DR. H. M CHANCE, | 19 |
| The New Mining Code of Mexico. By RICHARD E. CHISM, M.E., | 34 |
| The Iron Ores of Pictou County, Nova Scotia. By E. GILPIN, JR., A.M., F.G.S., F.R.S.C., | 54 |
| The Microscopic Structure of Iron and Steel. By F. LYNWOOD GARRISON, | 64 |
| A Simple Apparatus for Determining the Relative Strength of Explosives. By S. WHINERY, | 75 |
| Colored Mining Labor. By ALFRED F. BRAINERD, | 78 |
| The Utilization of the Iron and Copper Sulphides of Virginia, North Carolina and Tennessee. By C. R. BOYD, | 81 |
| The Influence of Temperature in Steel-Making on the Behavior of the Ingots in Rolling. By JOHN W. CABOT, | 84 |
| The Straight or No-Bosh Blast Furnace. By W. J. TAYLOR, | 88 |
| Experiments with Bolts and Screw-Threads. By MAJOR WILLIAM R. KING, U. S. Engineer, | 90 |
| Treatment of Roasted Pyrites by the Longmaid and Claudet Processes for the Extraction of Gold and Silver. By T. EGLESTON, PH.D., | 93 |
| The Manufacture of Steel Castings. By P. G. SALOM, | 118 |
| The Durham Blast-Furnace. By B. F. FACKENTHAL, JR., | 130 |
| Further Notes on the Clapp and Griffiths Process. By ROBERT W. HUNT, | 139 |
| The Flow of Air and Other Gases. By FRED. W. GORDON, | 146 |
| Gordon's Improved Whitwell-Cowper Fire-Brick Hot-Blast Stove. By VICTOR O. STROBEL, | 159 |
| The Geology and Mineral Resources of Sesquachee Valley, Tennessee. By W. M. BOWRON, | 172 |
| The Sulphide-Deposit of South Iron Hill, Leadville, Colorado. By FRANCIS T. FREELAND, B. S., | 181 |
| Biographical Notice of Charles O. Thompson. By PHILIP W. MOEN, | 190 |
| The "Centennial" and "Lotta" Gold Properties, Coahuila, Mexico. By DR. PERSIFOR FRAZER, | 196 |
| Quicksilver-Condensation at New Almaden. By SAMUEL B. CHRISTY, | 206 |
| Note on An Exhibition of Banded Structure in a Gold Vein. By CHARLES M. ROLKER, | 265 |
| Notes on Certain Iron-Ore Deposits in Colorado. By CHARLES M. ROLKER, | 266 |
| Notes on the Leadville Ore-Deposits. By CHARLES M. ROLKER, | 273 |
| The Upper Measure Coal-Field of Tennessee. By HENRY E. COLTON, | 292 |
| PROCEEDINGS OF THE XLIIId MEETING, HALIFAX, N. S., September, 1885, | 309 |
| PAPERS OF THE HALIFAX MEETING, September, 1885, | 325 |
| The Engineer and the Wage-Earner. By J. C. BAYLES, | 327 |
| The Amalgamation of Gold-Ores, and the Loss of Gold in Chloridizing-Roasting, with Especial Reference to Roasting in a Stetefeldt Furnace. By C. A. STETEFELDT, | 336 |
| The Present Value of Steel Castings. By ARTHUR V. ABBOTT, | 351 |
| The Homogeneity of Open-Hearth Steel. By H. H. CAMPBELL, | 358 |
| The Work of the Blast-Furnaces of the North Chicago Rolling-Mill Co. By FRED. W. GORDON, | 362 |
| Note on a Self Dumping Water-Tank. By WILLARD IDE PIERCE, | 371 |
| Estimation of Manganese, Carbon, and Phosphorus in Iron and Steel. By BYRON W. CHEEVER, | 372 |
| Mr. E. D. Campbell's Colorimetric Process for Estimating Phosphorus in Iron and Steel. By BYRON W. CHEEVER, | 382 |
| A New Method for the Determination of Phosphorus in Iron and Steel. By J. B. MACKINTOSH, | 385 |
| Lixiviation and Amalgamation Tests. By F. W. CLARK, | 395 |
| Note on the Contraction of Iron on Sudden Cooling. By HENRY M. HOWE, A. M., S. B., | 400 |
| The Pictou Coal-Field. By HENRY S. POOLE, F.G.S., Assoc. R.S.M., | 403 |
| The Wolf Benzine-Burning Safety-Lamp. By E. J. SCHMITZ, | 410 |
| The Product and Exhaustion of the Oil-Regions of Pennsylvania and New York. By CHARLES A. ASHBURNER, | 419 |

PAGE
The Geology of Natural Gas. By CHARLES A. ASHBURNER, . . . 428
Topographical Models: Their Construction and Uses. By A. E. LEHMAN, . 439
Basic Refractory Materials. By T. EGLESTON, PH.D., . . . . . 455
An Electrical Furnace for Reducing Refractory Ores. By DR. T. STERRY HUNT, . . . . . 492
Note on the Apatite Region of Canada. By T. STERRY HUNT, . . . 495
Improvements in Ore-Crushing Machinery. By S. R. KROM, . . . 497
The Manufacture of Iron in Canada. By JAMES HERBERT BARTLETT, . 508
The Sydney Coal-Field, Cape Breton, N. S. By W. ROUTLEDGE, M.E., . 542
The Distribution and Proportions of American Blast-Furnaces. By JOHN BIRKINBINE, . . . . . 561
The Improved Brückner Cylinders. By R. W. RAYMOND, . . . . . 576
The Specific Gravity of Low-Carbon Steel. By GEORGE S. MILLER, . . 583
PROCEEDINGS OF THE XLIVTH (ANNUAL) MEETING, PITTSBURGH, February, 1886, . . . . . 587
PAPERS OF THE PITTSBURGH MEETING, February, 1886, . . . . . 607
Professional Ethics. By J. C. BAYLES, . . . . . 609
The Geology of the Pittsburgh Coal-Region. By J. P. LESLEY, . . . 618
Pittsburgh and Vicinity—A Brief Record of Seven Years' Progress. By WILLIAM P. SHINN, . . . . . 657
The Nova Scotia Gold Mines. By E. GILPIN, JR., A.M., F.G.S., F.R.S.C., etc., 674
The Mineral Resources of the Hudson's Bay Territories. By ROBERT BELL, B.A.SC., M.D., LL.D., . . . . . 690
The Manufacture of Fire-Brick at Mount Savage, Maryland. By ROBERT ANDERSON COOK, A.M., . . . . . 698
The Classification and Composition of Pennsylvania Anthracites. By CHARLES A. ASHBURNER, . . . . . 706
Proposed Apparatus for Determining the Heating Power of Different Fuels. By WILLIAM KENT, M.E., . . . . . 727
The Process Used at the Comstock for Refining Coppery Bullion Produced by Amalgamating Tailings. By A. D. HODGES, JR., . . . . . 731
Note on a Deposit of Fire-Sand in Clinton County, N. Y. By ALFRED F. BRAINERD, M.E., . . . . . 757
The Sampling of Cast-Iron Borings. By PORTER W. SHIMER, M.E., . . 760
Note on the Determination of Small Quantities of Titanium in Irons and Steels. By HORACE L. WELLS, . . . . . 763
Note on the Reduction of Ferric Solutions by the Use of Amalgamated Zinc and Platinum Foil. By ALFRED L. BEEBE, . . . . . 766
Note on a Cupel-Machine. By PROFESSOR CHARLES E. WAIT, . . . . 767
Note on the Use of Gasoline-Gas in a Chemical Laboratory. By PROFESSOR CHARLES E. WAIT, . . . . . 769
A New Method of Laying Submarine Tunnels and Tubes. By RICHARD P. ROTHWELL, . . . . . 770
Mitis-Castings from Wrought-Iron or Steel. By PETTER OSTBERG, . . 773
A Chilled Blast-Furnace Hearth. By JAMES GAYLEY, . . . . . 779
Biographical Notice of Oswald J. Heinrich. By R. W. RAYMOND, . . 784
Peculiar Phenomena in the Heating of Open-Hearth and Bessemer Steel. By WILLIAM GARRETT, . . . . . 789
Notes on the Constitution of Cast-Iron. By C. B. DUDLEY and F. N. PEASE, 795
Geology of the Low Moor, Virginia, Iron-Ores. By BENJ. LYMAN, . . 801
Iron-Ore Deposits of Southern Utah. By W. P. BLAKE, . . . . . 809
Recent Failures of Steel Boiler-Plates. By WILLIAM KENT, M.E., . . 812
Soft Steel for Boiler-Plates. By ALFRED E. HUNT, . . . . . 826
Operation of Warwick Furnace, Pennsylvania, from August 27th, 1880, to September 1st, 1885. By JOHN BIRKINBINE, . . . . . 833
The Mining Compass and Trigonometer. By ERICH G. GAERTNER, . . 870
The Cornwall Iron-Ore Mines, Lebanon County, Pa. By E. V. d'INVILLIERS, 873
The Product of the Hibernia Iron-Mine, N. J. By J. WESLEY PULLMAN, . 904
The Microscopic Structure of Car-Wheel Iron. By F. LYNWOOD GARRISON, F. G. S., . . . . . 913
The Clapp-Griffiths Converter: Later Practice and Commercial Results. By J. P. WITHEROW, . . . . . 919
The Heine Safety-Boiler. By E. D. MEIER, C.E., . . . . . 941
Colorado Ore-Deposits (Correction), . . . . . 948

# AMERICAN INSTITUTE OF MINING ENGINEERS.

## OFFICERS.

MAY, 1886.

### President.

R. H. RICHARDS,
Boston, Mass.

### Vice-Presidents.

| | |
|---|---|
| J. D. WEEKS, | Pittsburgh, Pa. |
| JAMES F. LEWIS, | New York City. |
| W. B. COGSWELL, | Syracuse, N. Y. |

(Term expires February, 1888.)

| | |
|---|---|
| JOHN FULTON, | Johnstown, Pa. |
| RICHARD PEARCE, | Denver, Colorado. |
| C. A. STETEFELDT, | New York City. |

(Term expires February, 1887.)

### Managers.

| | |
|---|---|
| W. G. NEILSON, | Philadelphia. |
| J. E. JOHNSON, | Longdale, Va |
| H. M. HOWE, | Boston, Mass. |

(Term expires February, 1889.)

| | |
|---|---|
| EDGAR S. COOK, | Pottstown, Pa. |
| FRANK FIRMSTONE, | Glendon, Pa. |
| GEORGE W. MAYNARD, | New York City. |

(Term expires February, 1887.)

| | |
|---|---|
| C. A. ASHBURNER, | Philadelphia, Pa. |
| W. E. C. COXE, | Reading, Pa. |
| E. GYBBON SPILSBURY, | Haile Mine, S. C. |

(Term expires February, 1888.)

### Secretary.

R. W. RAYMOND,
13 Burling Slip, New York City.

### Treasurer.

THEODORE D. RAND,
Philadelphia.

# Honorary Members.

I. Lowthian Bell, . . . . . Middlesbrough, Eng.
Peter Ritter v. Tunner, . . . . . Leoben, Austria.
Rich. Åkerman, . . . . . Stockholm, Sweden.
Dr. Thomas M. Drown, . . . . . Boston, Mass.
Dr. John Percy, . . . 1 Gloucester Crescent, Hyde Park, London, Eng.
Prof. Theodor Richter, . . . . . Freiberg, Saxony.
Prof. Dr. Hermann Wedding, . . . . . Berlin, Prussia.

# Foreign Members.*

Allport, Charles J., . . . . . Sheffield, England.
Althans, Oberbergrath Ernst F., . . . . . Breslau, Prussia.
Amiot, H., . . . . . Clermont-Ferrand, Puy de Dôme, France.
Arbel, Lucien, . . . . . Rive de Gier, Loire, France.
Beaulieu, Ad. le Hardy de, . . . 93 Rue d'Arlon, Brussels, Belgium.
Beaumont, Major Fred., . 2 Westminster Chambers, Victoria St., London.
Beck, Alexander, . . . . 2 Rue des Orphelins, Mons, Belgium.
Bodmer, J. J., . . . . . 23 The Grove, Hammersmith, London.
Brassert, Berghauptmann, Dr., . . . . . Bonn, Prussia.
Brogden, James, . . . . . 5 Queen's Square, Westminster, London.
Burthe, P. L., . . . . . 38 Rue Vaneau, Paris, France.
Copeland, C. J., . . . . . Barrow in Furness, England.
Crossley, William, . . . . . Dalton in Furness, England.
Deby, Julien, . . . . . 3 Lombard Street, London.
Fayn, Joseph, . . . . . Liége, Belgium.
Frenzel, August, . . . . . Freiberg, Saxony.
Gaetzschmann, Prof. Moritz, . . . . . Freiberg, Saxony.
Gillon, Prof. Aug., . . . . 47 Boulevard d'Avroy, Liége, Belgium.
Höfer, Prof. Hanns, . . . . . Leoben, Austria.
Henry, Adolph, . . . . . Rive de Gier, Loire, France.
Jordan, Prof. S., . . . . . 5 Rue Viéte, Paris, France.
Jossa, Prof. Nicholas, . . . . . St. Petersburg, Russia.
Knowles, J. H., . . . . . Newport, Monmouthshire, Wales.
Kreischer, Prof. C. G., . . . . . Freiberg, Saxony.
Kupelwieser, Prof. Franz, . . . . . Leoben, Austria.
Laveleye, Ed. de, . . . . . Liége, Belgium.
McPherson, George, Wednesbury Oak Iron Works, Tipton, Staffordshire, Eng.
Martin, Pierre Emil, . . . . . 12 Rue Chaptal, Paris.
Monks, Frederick, . . . . . Warrington, England.

---

* The names in this list are those of the foreign members elected before February, 1880, at which time (see Proceedings of the New York Meeting, *Transactions*, vol. viii., p. 281) Rules I., II. and V. were so amended as to abolish the distinctive class of foreign members, as previously existing. All foreign members elected since that date are included in the general list of "Members and Associates" on page vii.

NICOLSKY, PROF. L., . . . . . St. Petersburg, Russia.
NOBLET, A., . . . . . 24 Rue d'Archis, Liége, Belgium.
PATERA, BERGRATH AD., . . Geologische Reichsanstalt, Vienna, Austria.
POSEPNY, BERGRATH FRANZ, . . . . . Pribram, Bohemia.
POURCEL, ALEXANDRE, . . . . . Bilbao, Spain.
REMIMONT, ARM., . . . . . Seraing, Belgium.
ROGERSON, JOHN, . . . . . Croxdale Hall, Durham, England.
ROLLAND, G., . . . . . 23 Quai Voltaire, Paris, France.
SCHMIDT, DR. ADOLF, . . . . . Heidelberg, Baden.
SERLO, BERGHAUPTMANN, DR., . . 89 W. Wilhelmstrasse, Berlin, Prussia.
SONTAG, HUGO, . . . . . Cologne, Prussia.
STRONGITHARM, AUG. H., . . . . . Barrow in Furness, England.
VALTON, FERDINAND, . . . . . 20 Rue Lepelletier, Paris, France.
WENDEL, H. DE, . . . . . Hayange, Lorraine, Prussia.
WESTRAY, JOHN, . . Carlin How, near Salisbury by the Sea, England.
WILLIAMS, EDWARD, . . Cleveland Lodge, Middlesbro'-on-Tees, England.
WINTER, ADOLPH, . . . . . Wiesbaden, Germany.
WITTELSBACH, OTTO, . . . Taegerweilen, Canton Thurgau, Switzerland.
YBARROLA, J. RAMON DE, . . . . . City of Mexico.

# Members and Associates.

MAY, 1886.

THOSE MARKED THUS * ARE MEMBERS; MARKED THUS ** ARE LIFE MEMBERS; MARKED THUS † ARE ASSOCIATES. THE FIGURES AT THE END OF THE ADDRESS INDICATE THE YEAR OF ELECTION.

*ABADIE, EMILE R., . . Box A. O., Grass Valley, Nevada Co., Cal. '76
*ABBOTT, ARTHUR V., . . . Room 100, 35 Broadway, New York City. '82
†ACKER, E. O'C., . . . . Navy Department, Washington, D. C. '86
*ADAMS, WILLIAM H., . . . . 71 Wall Street, New York City. '80
*ADDY, MATTHEW, . . . . . Cincinnati, O. '84
*AGASSIZ, PROF. ALEXANDER, . . . . . Cambridge, Mass. '77
*AIKEN, ROBERT H., . . . . . Wickes, Montana. '84
*AINEY, WILLIAM H., . . . . . Allentown, Pa. '84
*ALDEN, P. E., . . . . . Monroeton, Pa. '84
*ALDRICH, TRUMAN H., . . . Southern Avenue, Cincinnati, Ohio. '78
*ALDRICH, W. F., . . . . . Aldrich, Alabama. '81
*ALEXANDER, ARCH. A., . . . . . San Antonio, Texas. '82
*ALEXANDER, CURTIS, . . . . . Maryville, Mo. '84
*ALEXANDER, JOHN S., . . . 1935 Arch Street, Philadelphia. '72
*ALLEN, JOSEPH H., . . . Care Clifton Coal Co., Mannington, Ky. '82
*ALLEN, JNO. H., . . . . . Box 733, Pueblo, Colorado. '84
*ALLISON, ROBERT, . . . . . Port Carbon, Pa. '86
*ALMY, WILLIAM F., . . . . . Fall River, Mass. '80
*AMSLER, CARL, . . . Mackintosh, Hemphill & Co., Pittsburgh, Pa. '86
†AMY, ERNEST J. H., . . 18 W. Twenty-seventh Street, New York City. '85
*ANDERSON, J. F. T., . . . Tredegar Iron Works, Richmond, Va. '85
*ANGSTROM, CARL, . . . . . Domnarfort, Sweden. '85
*APPLETON, E. C, . . . . . Ashland, Nebraska. '80

*Archibald, Chas., . . . . . Gowrie Mines, Cow Boy, N. S. '86
*Arents, Albert, . . P. O. Box 15, West End, Alameda Co., Cal. '82
*Armstrong, H. W., . . . . Metcalf, Paul & Co., Pittsburgh, Pa. '79
*Arnberg, C. T., . Albany & Rensselaer Iron and Steel Co., Troy, N. Y. '81
†Arnold, J. B., . . . . . Aurora, Ill. '76
*Arnolds, Hugo, . . . . . P. O. Box 46, Prescott, Arizona. '82
*Ashburner, Charles A., . . . 907 Walnut Street, Philadelphia. '75
*Ashburner, William, . . 1014 Pine Street, San Francisco, Cal. '72
*Atha, Benjamin, . . . . . Newark, N. J. '84
*Atkins, William, . . . . . Pottsville, Pa. '81
**Attwood, George, . . Durmast House, Ringwood, Hants, England. '75
*Auchy, George, . . . . . Riegelsville, Pa. '81
*Austin, J. B., . . . . . Roanoke, Va. '83
*Austin, T. S., . . . . . Salt Lake City, Utah. '83
*Austin, W. Lawrence, . . . . . Toston, Montana. '82
*Ayres, W. S., . . . . . Allamuchy, N. J. '78

*Babcock, Geo. H., . . . . 30 Cortlandt Street, New York City. '85
*Bachman, F. E., . . . . . Middletown, Pa. '80
*Bacon, Chas. A., . Care Marcial & Co., 36 Broadway, New York City. '85
*Bacon, D. H., . . . . . Ishpeming, Mich. '86
*Bailey, Chas., . . . Pittsburgh Steel Casting Co., Pittsburgh, Pa. '86
*Bailey, Edward, . . . . . Pottstown, Pa. '84
*Bailey, Edward, Jr., . . . 31 S. Front Street, Harrisburg, Pa. '83
*Bailey, Gilbert E., . . . . Etta Mine, Harney P. O., Dakota. '82
*Bailey, Jackson, . . . . 96 Fulton Street, New York City. '80
†Baker, Charles Henry, . . Care Metcalf, Paul & Co., Pittsburgh, Pa. '82
*Baker, Richard D., . . . . 216 S. Third Street, Philadelphia. '82
*Baker, S. C., . . . . . Altoona, Pa. '84
†Bakewell, Thos. W., . . . . . Pittsburgh, Pa. '86
*Baldwin, S. W., . . . . . 160 Broadway, New York City. '78
*Banks, John H., . . . . School of Mines, New York City. '83
*Barnes, F. W., . . . . . Simmering, Vienna, Austria. '86
*Barnes, O. W., . . . . . 57 Broadway, New York City. '81
*Barnes, Phineas, . . . . . Lock Box 1479, Pittsburgh, Pa. '75
*Barnes, Walter U., . . . . . Littleton, Mass. '80
*Barnhill, B. B., . . . . . Joggins Mines, Nova Scotia. '84
†Barns, George T., . . . . 224 S. Fourth Street, Philadelphia. '84
*Barr, J. N., . . . . . Milwaukee, Wis. '84
*Barrett, Edgar G., . . . . 116 Dearborn Street, Chicago, Ill. '85
*Bartlett, J. C., . . . . . Taunton, Mass. '77
*Bartlett. J. H., . . . Standard Building, Montreal, Canada. '85
*Bartol, George, . . . Otis Iron and Steel Co., Cleveland, Ohio. '79
*Barus, Carl, . . . U. S. National Museum, Washington, D. C. '84
*Bayles, James C., . . . . 66 Duane Street, New York City. '78
*Beattie, James F., . . . . . Connellsville, Pa. '82
*Beebe, Alfred L., . . 58 E. Sixty-eighth Street, New York City. '83
*Beeger, Hermann, . . . . Denver Club, Denver, Colorado. '82
*Bel, J. Marc, . . . . . 21 rue de Berne, Paris, France. '84
*Bell, Dr. Robert, . . . . Geological Survey, Ottawa, Canada. '85

†BENIS, FRED. P., . . . . 166 Bridge Avenue, Davenport, Iowa. '85
*BENEDICT, W. DE L., . . . . 32 Liberty Street, New York City. '83
*BENTLEY, ROBERT, . . . . . Lowellville, Ohio. '84
*BERDELL, THEODORE, . . 42 E. Twenty-fifth Street, New York City. '82
*BERG, WALTER G., Ass't Eng'r's Office, L. V. R. R., Mauch Chunk, Pa. '81
*BERLIN, PROF. A. P., . . . . . Slatington, Pa. '82
†BERRY, W. G., . . . . 12 E. Fifty-fourth Street, New York City. '85
*BERTOLET, ALFRED S., . . . . Crown Point, Essex Co., N. Y. '75
*BEVERIDGE, ROBERT, . . . . . Walkerville, Montana. '84
*BIDDLE, WILLIAM F., . . . 209 S. Third Street, Philadelphia. '81
†BIEN, J. R., . . . 231 W. Fifty-seventh Street, New York City. '86
*BIERWIRTH, L. C., . . . . Dover, N. J. '75
*BILDT, CARL W., . . . . Worcester, Mass. '86
*BILLIN, CHARLES E., . . . . 186 Dearborn St., Chicago, Ill. '75
*BILLING, G., . . . . P. O. Box 211, Socorro, N. M. '82
*BILLINGS, G. H., . . . . Norway Iron Works, Boston, Mass. '77
*BINSSE, HENRY L., . . 40 W. Nineteenth Street, New York City. '75
*BIRDS, E. J., JR., . . . . Ironton, Ohio. '86
*BIRKINBINE, JOHN, . . . . 144 S. Fourth Street, Philadelphia. '75
*BLAIR, ANDREW A., . . . . 919 Chant Street, Philadelphia. '75
*BLAIR, GEO. D., . . . . Spruce Creek, Pa. '84
†BLAKE, C. G., . . . . 30 W. Third Street, Cincinnati, O. '86
*BLAKE, F. C., . . . . Mansfield Valley, Allegheny Co., Pa. '77
*BLAKE, FRANCIS H., . . . . Pinal, Arizona. '84
*BLAKE, THEODORE A., . . . . New Haven, Conn. '80
*BLAKE, PROF. W. P., . . . . New Haven, Conn. '71
*BLAKSLEE, A. P., . . . . Delano, Pa. '84
*BLANDY, JOHN F., . . . . Sulphur Creek, Colusa Co., Cal. '71
*BLEECKER, CHARLES P., . . 11 West 129th Street, New York City. '80
*BLOSS, RICHARD P., . . . . Palmer, N. Y. '83
*BLOW, A. A., . . . . P. O. Box 228, Leadville, Colorado. '82
*BOEHMER, MAX, . . . . Box 765, Leadville, Colorado. '84
*BOGART, JOHN, . . . 127 East Twenty-third Street, New York City. '76
*BOGGS, WILLIAM R., JR., . . Grand View M. & S. Co., Rico, Colo. '82
*BOLLER, A. P., . . . . 71 Broadway, New York City. '80
*BOOTH, HENRY, . . . . 26 Garfield Place, Poughkeepsie, N. Y. '74
*BORDA, E., . . . . P. O. Box 1696, Philadelphia. '75
*BOVEY, PROF. HENRY T., . . 31 McTavish Street, Montreal, Canada. '78
*BOWDEN, J. H., . . . . Lock Box 784, Wilkes-Barre, Pa. '71
*BOWIE, A. J., JR., . . . P. O. Drawer 2220, San Francisco, Cal. '72
*BOWMAN, AMOS, . . . . . Sussex Street, Ottawa, Canada. '86
*BOWRON, JAMES, . . . . . Nashville, Tenn. '78
*BOWRON, WILLIAM M., . . . . . South Pittsburg, Tenn. '81
*BOYD, C. R., . . . . . Wytheville, Va. '76
*BOYD, HENRY A., . . . . . Box 162, McKeesport, Pa. '86
*BOYER, JEROME L., . . . . . Reading, Pa. '84
*BOYLE, THOS. G., . . . . . Bissell Block, Pittsburgh, Pa. '86
*BRADLEY, G. L., . . . . . Pomfret Center, Conn. '74
*BRAEM, HENRI M., . . . . . 52 Broadway, New York City. '80
*BRAINERD, ALFRED F., . . . . . Birmingham, Ala. '79

| | | |
|---|---|---|
| *Bramwell, J. H., | Roanoke, Va. | '71 |
| *Branner, Prof. John C., | Bloomington, Ind. | '84 |
| †Braschi, V. M., | 23 Park Place, New York City. | '81 |
| *Bray, William A., | Leadville, Colorado. | '80 |
| *Breckenridge, Cabell, | 1045 Scott Street, Covington, Ky. | '84 |
| *Bridgman, H. L., | 1203 Locust Street, Des Moines, Iowa. | '79 |
| *Brinley, Charles A., | Blue Island, Ills. | '79 |
| *Brinsmade, Henry N., | 108 E. Thirty-first Street, New York City. | '81 |
| *Britton, J. Blodget, | 339 Walnut Street, Philadelphia. | '72 |
| *Brock, Charles, | Manhattanville, New York City. | '81 |
| *Brodhead, Calvin E., | Flemington, N. J. | '76 |
| **Brodie, W. M., | Batopilas, Chihuahua, Mexico. | '72 |
| *Brooke, George, | Birdsboro, Berks Co., Pa. | '81 |
| *Brooks, R. G., | Lock Box 124, Scranton, Pa. | '84 |
| †Brooks, T. B., | Newburgh, N. Y. | '72 |
| †Brown, A. C., | Marinette, Wis. | '80 |
| *Brown, Alexander E., | 40 Fifth Ave., Cleveland, Ohio. | '75 |
| *Brown, D. P., | Lost Creek, Schuylkill Co., Pa. | '72 |
| *Brown, Edward L., | Care Inman S. S. Line, 32 S. Clark St., Chicago, Ill. | '81 |
| †Brown, Fayette, | 863 Euclid Avenue, Cleveland, Ohio. | '75 |
| *Brown, Harvey H., | 101 St. Clair Street, Cleveland, Ohio. | '76 |
| *Brown, J. Stuart, | Brown & Co., Pittsburgh, Pa. | '81 |
| †Brown, Louis, | 30 Liberty Street, New York City. | '85 |
| *Brown, Walter Lee, | Lock Box 1820 Aurora, Ill. | '84 |
| *Bruckman, Fredrick, | 138 Clarkson Street, Denver, Colorado. | '82 |
| *Bruckner, Wm., | Box 13, Anaconda, Mont. | '85 |
| *Bruner, Abram, | P. O. Box 146, Allegheny, Pa. | '82 |
| **Brunton, D. W., | P. O. Box 2470, Denver, Colorado. | '83 |
| *Brush, Prof. George J., | New Haven, Conn. | '75 |
| *Buck, Stuart M., | Coalburgh, Kanawha Co., W. Va. | '71 |
| *Bulkley, F. G., | P. O. Box 883, Leadville, Colorado. | '82 |
| *Bulkley, Henry W., | 149 Broadway, New York City. | '79 |
| *Bulley, Reginald H., | Canton, Ohio. | '78 |
| *Bullock, M. C., | 199 Lake Street, Chicago, Ill. | '74 |
| *Bunce, Walter H., | Box 133, Leadville, Colo. | '85 |
| *Bunning, Chas. Z., | Warora, Central Provinces, East Indies. | '85 |
| *Bunsen, Robert, | Leadville, Colorado. | '76 |
| *Burchell, H. C., | St. John's, Newfoundland. | '83 |
| *Burchell, James T, | Sydney, Cape Breton, Nova Scotia. | '83 |
| **Burden, H. H., | Troy, N. Y. | '83 |
| *Burden, Henry, | Troy, N. Y. | '79 |
| *Burden, I. Townsend, | Troy, N. Y. | '76 |
| *Burden, James A., | Troy, N. Y. | '76 |
| †Burden, William F., | 111 First Street, Troy, N. Y. | '83 |
| †Burke, M. D., | 45 Wiggins Building, Cincinnati, Ohio. | '74 |
| *Burlingame, E. E., | 446 Lawrence Street, Denver, Colorado. | '82 |
| †Burnet, S. F., | St. Louis Water Works, St. Louis, Mo. | '81 |
| *Burnham, William, | 220 S. Fourth Street, Philadelphia. | '76 |
| **Burt, Charles S., | Newberry, Mich. | '82 |
| *Burt, Lee, | 49 Newberry & McMillen Building, Detroit, Mich. | '86 |

*Bush, E. Renshaw, . . . . . 10 Wall Street, New York City. '85
†Butler, Cyrus, . . . . . 24 Cliff Street, New York City. '72
*Butters, Charles, . . . . . 52 Broadway, New York City. '83
*Byers, A. M., . . . . . 98 Water Street, Pittsburgh, Pa. '86

†Cabeen, F. von A., . . . . . 400 Chestnut Street, Philadelphia. '82
*Cabot, John W., . . . . . Box 961, Bellaire, O. '80
*Cadle, Cornelius, Jr., . . . . . Blocton, Bibb Co., Alabama. '83
†Calman, Albert, . . 332 W. Fifty-sixth Street, New York City. '81
*Camp, James M., . Twenty-sixth and Rail Road Sts., Pittsburgh, Pa. '83
*Campbell, Edward S., Jr., Candela, Coahuila, Mexico, via Laredo, Texas. '86
*Campbell, H. H., . . . . . Steelton, Dauphin Co., Pa. '81
*Canby, R. C., . . . . . Pueblo, Colorado. '82
†Canfield, A. Cass, . . 60 W. Fifty-fourth Street, New York City. '76
*Canfield, Fred. A., . . . . . Dover, N. J. '74
*Carll, John F., . . . . . Pleasantville, Pa. '86
**Carnegie, Thomas M., . . . 48 Fifth Avenue, Pittsburgh, Pa. '78
*Carson, A. C., . . . . . Butte City, Montana. '84
*Carson, James P., . . . . 16 Exchange Place, New York City. '82
*Carter, Frank, . . . . . Pottsville, Pa. '73
†Carter, George T., . . . . 62 Wood Street, Pittsburgh, Pa. '81
*Chadwick, Walter M., . . . . . Bergen Point, N. J. '83
*Chalfant, John W., . . . . . Pittsburgh, Pa. '73
*Chamberlain, H. S., . . . . . Chattanooga, Tenn. '75
*Chambers, R. C., . . . . . Box 601, Salt Lake City, Utah. '86
*Chance, Dr. H. Martyn, . . 123 N. Nineteenth Street, Philadelphia. '74
*Channing, J. Parke, . . . . . Houghton, Mich. '84
*Chanute, Arthur, . . . . P. O. Box 750, Leadville, Colorado. '82
*Chanute, O., . . . . . Kansas City, Mo. '79
*Chaper, Maurice, . . . 31 Rue St. Guillaume, Paris, France. '79
*Chapin, P. E., . . . . . Johnstown, Pa. '83
*Charleton, A. G., . Rishton, Charters Towers, Queensland, Australia. '81
*Chase, Frank D., . . Butte City Sampling Works, Butte City, Mont. '84
*Chauvenet, S. H., . . . . . Robesonia, Berks Co., Pa. '81
*Chazal, Philip E., . . . . . Box 362, Columbia, S. C. '81
*Cheever, Prof. B. W., . University of Michigan, Ann Arbor, Mich. '82
*Chenhall, James W., Crown Villas, Morriston, R. So., South Wales, G. B. '85
*Cherry, William S., . . . . . Streator, La Salle Co., Ill. '75
*Chess, Harvey B., . . . . Chess, Cook & Co., Pittsburgh, Pa. '80
*Chester, Prof. A. H., . Hamilton College, Clinton, Oneida Co., N. Y. '71
*Childs, Albert H., . . . . 83 Fourth Avenue, Pittsburgh, Pa. '79
*Chisolm, Frederic F., . . . . . Denver, Colorado. '83
*Chism, Richard E., . . . . Saltillo, Mexico, via Laredo, Texas. '80
*Chouteau, Pierre, . . . . . St. Louis, Mo. '76
*Christie, Fred. W., . . . . . Bedford Station, Halifax, N. S. '85
*Christy, Prof. S. B., . . . . State University, Berkeley, Cal. '83
*Church, Prof. John A., . . . . . Brandon, Vt. '72
*Church, John B., . . . . . Geneva, N. Y. '81
*Church, Townsend V., . . 400 Chestnut Street, Philadelphia, Pa. '82
*Church, W. D., . . . . . Topeka, Kansas. '84

| | | |
|---|---|---|
| *Church, Walter S., | 215 Stewart Building, Broadway, New York City. | '81 |
| *Churchill, A. D., | 39 Broadway, New York City. | '80 |
| †Chynoweth, B. F., | Greenland, Mich. | '76 |
| †Claghorn, Clarence R., | Bernice, Pa. | '84 |
| *Clapp, Chas. E., | Pittsburgh, Pa. | '85 |
| *Clapp, George H., | 98 Fourth Avenue, Pittsburgh, Pa. | '83 |
| *Clark, Ellis, Jr., | 462 N. Sixth Street, Philadelphia. | '74 |
| *Clark, F. W., | Institute of Technology, Boston, Mass. | '82 |
| *Clark, R. Neilson, | Leadville, Colorado. | '72 |
| †Clark, William A., | Butte, Montana. | '82 |
| *Clarke, E. A. S., | Union Steel Co., Chicago, Ill. | '85 |
| *Clarke, Thomas C., | 18 Broadway, New York City. | '76 |
| *Claussen, F. F., | U. S. Mint, New Orleans, La. | '76 |
| *Claypool, M. S., | Georgetown, Colorado. | '83 |
| †Claypool, W. M., | Deming, New Mexico. | '84 |
| *Clayton, James E., | P. O. Box 266, Baltimore, Md. | '75 |
| *Clayton, Joshua E., | P. O. Box 366, Salt Lake City, Utah. | '74 |
| *Clemens, Frank G., | Lost Creek, Schuylkill Co., Pa. | '81 |
| *Clemens, Geo. S., | Ashland, Pa. | '84 |
| **Clemes, J. H., | Penrhyn Lodge, Woodb'y Down, Finsb'y Park, London, N., Eng. | '81 |
| **Cliff, John, | Hancock, Mich. | '80 |
| *Clymer, Edward T., | Temple, Berks Co., Pa. | '82 |
| *Coe, W. W., | Roanoke, Va. | '83 |
| *Coffin, Charles E., | Muirkirk, Md. | '82 |
| *Coggin, F. G., | Lake Linden, Mich. | '80 |
| *Cogswell, W. B., | Room 25, White Building, Syracuse, N. Y. | '72 |
| *Colburn, Henry B., | Liberty, Bedford Co., Va. | '76 |
| *Colby, Albert L., | South Bethlehem, Pa. | '83 |
| **Collin, Emile, | 30 Avenue de Messine, Paris, France. | '86 |
| *Collin, Simon C., | Braddock, Pa. | |
| *Collingwood, Francis, | Elizabeth, N. J. | '82 |
| †Collins, H. E., | 34 Sims Block, Pittsburgh, Pa. | '76 |
| *Colton, Charles A., | 21 West Park Street, Newark, N. J. | '74 |
| *Colton, Henry E., | Chattanooga, Tenn. | '83 |
| *Colyar, Louis S., | Chattanooga, Tenn. | '85 |
| **Colvin, Verplanck, | Adirondack Survey Office, Albany, N. Y. | '81 |
| *Comstock, George S., | Mechanicsburg, Cumberland Co., Pa. | '81 |
| *Comstock, Theo. B., | P. O. Box 472, Champaigne, Ills. | '80 |
| *Conant, T. P., | Care of Harper & Bros., Franklin Square, N. Y. City. | '81 |
| *Cone, Jno. J., | 618½ Jersey Ave., Jersey City, N. J. | '85 |
| †Connell, W. A., | Portsmouth, Ohio. | '86 |
| *Constable, C., | 44 Exchange Place, New York City. | '75 |
| *Constable, James, Jr., | Glendon Iron Works, Easton, Pa. | '79 |
| *Converse, John H., | Baldwin Locomotive Works, Philadelphia. | '83 |
| *Cook, Edgar S., | Warwick Iron Co., Pottstown, Pa. | '77 |
| *Cook, Prof. George H., | State Geologist, New Brunswick, N. J. | '74 |
| *Cook, Robert A., | Mt. Savage, Md. | '83 |
| *Coolidge, Walter G., | 1st Nat. Bank Building, Chicago, Ill. | '82 |
| *Cooper, Edward, | 17 Burling Slip, New York City. | '74 |
| *Cooper, H. P., | Parryville, Pa. | '81 |

| | | |
|---|---|---|
| *Cooper, James R., | Houghton, L. S., Michigan. | '80 |
| *Cooper, William H., | 62 William Street, New York City. | '83 |
| †Cornell, A. B., | Youngstown, Ohio. | '72 |
| *Corning, Erastus, | 87 State Street, Albany, N. Y. | '78 |
| *Corning, Frederick G., | 78 Broadway, New York City. | '77 |
| *Coryell, Martin, | Lambertville, N. J. | '71 |
| *Coryell, Torbert, | Lambertville, N. J. | '83 |
| *Courtis, W. M., | 449 Fourth Avenue, Detroit, Mich. | '71 |
| *Coutie, Wm., | Troy, N. Y. | '84 |
| *Cowles, Alf. H., | Cleveland, Ohio. | '86 |
| *Cowles, Eugene H., | 47 Windsor Avenue, Cleveland, Ohio. | '86 |
| †Coxe, Alexander B., | Drifton, Luzerne Co., Pa. | '80 |
| *Coxe, Eckley B., | Drifton, Luzerne Co., Pa. | '71 |
| *Coxe, W. E. C., | Reading, Pa. | '74 |
| *Crafts, Walter, | 3 Deshler Block, Columbus, Ohio. | '71 |
| *Crawford, Hugh A., | 411 N. Third Street, St. Louis, Mo. | '75 |
| *Crawford, John J., | Placerville, El Dorado Co., Cal. | '73 |
| *Crawford, John L., | Newcastle, Pa. | '84 |
| *Cremer, J. H., | Edgar Thomson Steel Works, Braddock, Pa. | '75 |
| †Crerar, John, Jr., | 109 Dearborn Street, Chicago, Ill. | '84 |
| **Crocker, A. L., | Minneapolis, Minn. | '80 |
| *Crocker, George A., | 32 Cliff Street, New York City. | '79 |
| *Crooker, Ralph, Jr., | Swissvale, Pa. | '81 |
| *Crookston, A. W., | 19 Wellington Street, Glasgow, Scotland. | '80 |
| *Crowe, Thomas, | N. Chicago Rolling Mill Co., South Chicago, Ill. | '84 |
| *Crowther, Benjamin, | Etna, Allegheny Co., Pa. | '76 |
| *Croxton, Samuel W., | Canal Dover, Ohio. | '75 |
| *Cummer, F. D., | 345 Kennard Street, Cleveland, Ohio. | '83 |
| *Cummings, George P., | Marquette, Mich. | '81 |
| *Cunningham, James S., | Everett, Bedford Co., Pa. | '83 |
| *Cunningham, J. L., | Ringwood, Passaic Co., N. J. | '82 |
| *Curry, Henry M., | Lucy Furnaces, Pittsburgh, Pa. | '79 |
| *Curtis, Gram, | New Castle, Pa. | '80 |
| | | |
| *Dabney, Chas. W., Jr., | Raleigh, N. C. | '84 |
| *Daggett, Ellsworth, | Salt Lake City, Utah. | '73 |
| *Dagron, James G., | Care Keystone Bridge Co., Pittsburgh, Pa. | '84 |
| *Danforth, A. H., | South Pueblo, Colorado. | '82 |
| *Daniels, Fred. H., | 132 Lincoln Street, Worcester, Mass. | '76 |
| *Darley, E. C., | 322 Pine Street, St. Louis, Mo. | '83 |
| *Davenport, C. W., | Erie, Pa. | '81 |
| *Davenport, Russell W., | Midvale Steel Works, Nicetown, Philadelphia. | '77 |
| *Davidson, George M., Jr., | Care C. & N. W. Ry. C. Shops, Chicago, Ill. | '81 |
| *Davies, Geo. C., | Norway Furnace, Pottstown, Pa. | '86 |
| *Davis, Chester B., | 52 Montauk Block, Chicago, Ill. | '78 |
| *Davis, Prof. Floyd, | Blacksburg, Va. | '83 |
| *Davis, Henry C., | 205 Walnut Place, Philadelphia. | '81 |
| *Davis, Louis M., | Bolivar, Venezuela (care Harriman & Co., Trinidad). | '84 |
| †Davis, M. C., | 48 Fifth Avenue, Pittsburgh, Pa. | '86 |
| †Dayton, L. M., | 184 N. Second Street, Cincinnati, Ohio. | '84 |

*Dean, Geo. A., . . . . . Mingo Junction, Ohio. '86
*De Bardeleben, H. F., . . . . . Birmingham, Ala. '86
*De Camp, Alfred H., . . . . . Boonton, N. J. '83
*De Camp, E. F., . . . . . Halifax Club, Halifax, N. S. '85
*De Camp, W. S., . . . . . Lyons Falls, N. Y. '75
**De Crano, E. G., . . 5 Union Court, Old Broad St., London, Eng. '72
*De Deken, Albert, . . Edgar Thomson Steel Works, Braddock, Pa. '84
†Delahaye, F. Hébert, . . 3 Ave. de l'Observatoire, Paris, France. '85
*De Saulles, A. B., . . . . Oliphant Furnace, Fayette Co., Pa. '71
*De Schweinitz, P. B., . . . . . South Pueblo, Colorado. '82
*Derland, Asbury, . . . Boiling Springs, Cumberland Co., Pa. '82
*Deshayes, V., . . . . . Tamaris Gard, France. '85
*Desloge, John M., . . . . Bonne Terre, St. François, Co., Mo. '81
*Devereux, W. B., . . . . . Aspen, Colorado. '80
*Dewey, Fred. P., . . Smithsonian Institution, Washington, D. C. '77
*Dewey, Wm. P., . . . . . Union Club, San Francisco, Cal. '85
†Dimock, Clarence H., . . . . . Windsor, Nova Scotia. '86
*D'Invilliers, E. V., . . . . 711 Walnut Street, Philadelphia. '82
*Disston, H. C., . . . . . P. O. Box 1537, Philadelphia, Pa. '84
*Disston, Wm., . . . . . Philadelphia, Pa. '84
*Dixon, Douglas, . 6 Crosby Square, Bishopgate Street, London, Eng. '84
*Dodge, Wallace H., . . . . Dodge Manuf. Co., Mishawaka, Ind. '84
*Dods, John C., . . . . . Danville, Pa. '81
*Dominick, F. J., . . . . . 115 Broadway, New York City. '82
*Donaldson, William J., . . . 226 Walnut Street, Philadelphia. '81
*Dorsey, E. B., . . . . . 63 Broadway, New York City. '79
*Downs, W. F., . . . . Dixon Crucible Co., Jersey City, N. J. '83
*Doyle, Pat., . . . Care of Rev. James Doyle, Madras, India. '79
*Drinker, H. S., . . . . . 218 S. Fourth Street, Philadelphia. '71
**Du Bois, Prof. Aug. Jay, . . . . . New Haven, Conn. '75
*Dudley, Dr. Charles B., . . . . . Altoona, Pa. '78
*Dudley, P. H., . . . . . 66½ Pine Street, New York City. '75
*Dudley, Prof. W. L., . Miami Medical College, Cincinnati, Ohio. '84
*Duff, John, . . . . . Georgetown, Colorado. '83
**Dumont, John M., . . . . . Idaho Springs, Colorado. '82
*Duncan, John, . . . . . Calumet, Houghton Co., Mich. '80
*Duncan, M. M., . . . . . Rockwood, Tenn. '84
†Dunlap, Thomas, . . . . . Laird, Rockbridge Co., Va. '81
*Du Puy, Herbert, . . . 171 Western Avenue, Allegheny, Pa. '79
*Durfee, W. F., . . . . 89 Courtland Street, Bridgeport, Conn. '76
*Durkee, Henry R., . . . . 164 Dearborn Street, Chicago, Ill. '84
*Dwight, Arthur S., . Colorado Smelting Co., South Pueblo, Colorado. '85

*Earle, Frank C., . . . . P. O. Box 15, Tombstone, Arizona. '84
*Earnshaw, Alfred, . . . . 203 Walnut Place, Philadelphia. '81
*Earnshaw, Edward H., . . . . Chester Furnace, Chester, N. J. '84
*Eastwood, Prof. J. F., . . . . . Ann Arbor, Mich. '82
*Eckert, Henry S., . . . . . Reading, Pa. '84
†Eckert, Hunter, . . . . . Reading, Pa. '81
*Eckman, John W., . . . . . Port Kennedy, Pa. '84

†Edmunds, Frank W., . . . . P. O. Box 133, Troy, N. Y. '83
*Edwards, J. Warner, Delaware Avenue and Green Street, Philadelphia. '76
†Edwards, R. M., . . 143 West Sixteenth Street, New York City. '86
*Egleston, Dr. Thomas, . 35 West Washington Square, New York City. '71
*Eilers, A., . . . . . South Pueblo, Colorado. '71
*Elder, Geo. R., . . . . . Johnstown, Pa. '86
*Elliot, Matthew P., . . Crystal Plate Glass Works, Crystal City, Mo. '85
†Ely, E. B., . . Washington Building, 1 Broadway, New York City. '79
*Ely, Theodore N., . . . . . Altoona, Pa. '79
*Emanuel, W. H., . . . . . Box 2065, Denver, Colorado. '81
*Emerson, B. F., . . . . . Copper Falls, Keweenaw Co., Mich. '76
*Emerson, Prof. G. D., . . . . . Rolla, Phelps Co., Mo. '71
*Emery, A. H., . . . . . Stamford, Conn. '82
*Emery, Charles E., . . . . 22 Cortlandt Street, New York City. '80
*Emmerton, F. A., . . . . . Joliet, Ill. '84
†Emmons, Arthur B., . . . . . Newport, R. I. '85
*Emmons, S. F., . . . U. S. Geological Survey, Washington, D. C. '77
*Engle, George U., . . . 912 Mahontongo Street, Pottsville, Pa. '77
*Engelmann, Henry, . . . . . La Salle, Ill. '72
*Eoff, Charles W., . . . 1322 Jefferson Street, Kansas City, Mo. '84
*Estabrook, J. D., . . Coulter Street, Germantown, Philadelphia. '72
*Eurich, E. F., . . . . . Aurora, Ill. '74
*Eustice, George W., . . . . . Helstone, Cornwall, England. '82
*Eustis, W. E. C., . . . . 4 Pemberton Square, Boston, Mass. '76
*Evans, John D., . . . . . Chester, Morris Co., N. J. '80
*Eyre, Thos. T., . . . . . Liverpool, Manatee Co., Fla. '85

*Faber du Faur, A., . . . . 180 Pearl Street, New York City. '72
*Fackenthal, B. F., Jr., . . . . . Riegelsville, Pa. '80
*Fackenthal, Michael, . . . . . Hellertown, Pa. '80
*Fairchild, A. C., . . . Passaic Rolling Mill Co., Paterson, N. J. '77
*Falding, Frederick J., . . . . 81 New Street, New York City. '84
*Farrell, Austin, . . . Glamorgan Iron Co., Lewistown, Pa. '80
*Fegely, Isaac, . . . . . Pottstown, Pa. '83
*Felton, Edgar C., . . . . . Steelton, Dauphin Co., Pa. '81
*Felton, S. M., . . . . . 208 S. Fourth Street, Philadelphia. '81
*Ferguson, E. M., . . . . 104 Fifth Avenue, Pittsburgh, Pa. '78
†Ferguson, J. H., . . . . P. O. Box 2124, Denver, Colorado. '84
†Ferguson, Samuel T., . . . . . Minneapolis, Minnesota. '84
*Ferguson, Walton, . . . . 104 Fifth Avenue, Pittsburgh, Pa. '79
*Ferrill, Jos. L., . . 430 Washington Avenue, Philadelphia, Pa. '86
*Ferris, J. C., . . . . . Carthage, Ill. '83
*Feustman, L. P., . . . . P. O. Box 375, Leadville, Colorado. '82
*Field, Robert P., . . 237 S. Forty-second Street, W. Philadelphia. '73
*Fillebrown, John P., . . . . Secaucus, Hudson Co., N. J. '79
*Finley, C. B., . . . . . Philipsburg, Pa. '81
*Firmstone, Frank, . . . . Glendon Iron Works, Easton, Pa. '71
*Firmstone, H., . . . . . Longdale, Alleghany Co., Va. '75
*Fisher, Clark, . . . . . Trenton, N. J. '71
*Fisher, H. H., . . . . . Allentown, Pa. '80

| | | |
|---|---|---|
| *Fisher, John J., | Allentown, Pa. | '81 |
| *Fitzhugh, Charles L, | Shoenberger & Co., Pittsburgh, Pa. | '79 |
| *Flagler, John H., | 104 John Street, New York City. | '82 |
| *Fleming, H. S., | Dayton, Tenn. | '84 |
| *Fletcher, Benj., Jr., | Bridgeport, Conn. | '86 |
| *Fletcher, Chas. R., | Tucson, Arizona. | '85 |
| *Fohr, Franz, | Leadville, Colorado. | '75 |
| *Foote, Emerson L., | 411 N. Third Street, St. Louis, Mo. | '82 |
| *Foote, Herbert C., | 37 Arlington Court, Cleveland, Ohio. | '75 |
| *Ford, E. L., | Youngstown Steel Co., Youngstown, Ohio. | '79 |
| *Ford, S. Alfred, | Edgar Thomson Steel Co., Pittsburgh, Pa. | '75 |
| *Ford, Robert G., | Bellwood, Blair Co., Pa. | '82 |
| *Forsstedt, James, | Worcester, Mass. | '86 |
| *Forsyth, Robert, | Union Steel Co., Chicago, Ill. | '75 |
| *Forsyth, William, | Aurora, Ill. | '84 |
| *Foster, Ernest Le Neve, | Georgetown, Colorado. | '75 |
| *Foucar, Edouard L., | P. O. Box 107, El Paso, Texas. | '85 |
| *Fowler, A. L., | Box 127, Westfield, Mass. | '84 |
| **Francklyn, Charles G., | 48 Wall Street, New York City. | '80 |
| *Franklin, Walter S., | Ashland, Baltimore Co., Md. | '79 |
| **Frazer, Dr. Persifor, | 201 S. Fifth Street, Philadelphia. | '71 |
| *Frazer, Robert, | 209 S. Third Street, Philadelphia. | '76 |
| *Frazier, Prof. B. W., | Lehigh University, Bethlehem, Pa. | '71 |
| *Frear, Wm., | State College, Pa. | '85 |
| *Frecheville, R. J., | 5 Holyrood Place, Plymouth, England. | '84 |
| *Frecheville, William, | Hoover Hill, Randolph Co., N. C. | '84 |
| *Freeland, Francis T. | Iron Silver Mining Co., Leadville, Colo. | '85 |
| *Freeman, H. C., | Box 1, Alto Pass, Union Co., Ill. | '78 |
| †Freeman, William Coleman, | Cornwall, Lebanon Co., Pa. | '77 |
| *Frick, H. C., | 104 Fifth Avenue, Pittsburgh, Pa. | '79 |
| *Frick, Wm. C., | Danville, Pa. | '85 |
| *Fricke, F. G., | 96½ Fourth Avenue, Pittsburgh, Pa. | '79 |
| *Frink, George S., | Irondale, N. Y. | '85 |
| *Fritz, John, | Bethlehem, Pa. | '72 |
| *Frossard, John D., | 168½ Rue St. Denis, Montreal, Canada. | '85 |
| *Fry, John E., | Springfield Iron Co., Springfield, Ill. | '75 |
| *Fuller, Homer T., | Worcester, Mass. | '84 |
| *Fulton, Henry, | Georgetown, Colorado. | '81 |
| *Fulton, John, | Cambria Iron Co., Johnstown, Pa. | '72 |
| *Fulton, R. C., | Conshohocken, Pa. | '83 |
| *Furman, Howard V., | Cactus Club, Denver, Colorado. | '80 |
| *Fusz, Paul A., | 941 N. Second Street, St. Louis, Mo. | '79 |
| | | |
| *Gaertner, Erich G., | 127 Fulton Street, New York City. | '84 |
| *Gaither, Alfred, | 121 Broadway, Cincinnati, Ohio. | '86 |
| *Gallaher, P. C., | Leadville, Colorado. | '86 |
| *Gardner, G. Clinton, | 15 Broad Street, New York City. | '78 |
| *Gardner, George C., | Room 35, Portland Block, Chicago, Ill. | '83 |
| *Garrett, Albin, | 208 S. Fourth Street, Philadelphia. | '82 |
| *Garrett, William, | Oliver & Roberts Wire Co., Pittsburgh, Pa. | '81 |

*Garrison, Frank L., . . . . 1523 Girard Ave., Philadelphia. '83
*Garthwaite, E. H., . . . Care of W. W. Garthwaite, Oakland, Cal. '82
†Gatewood, R., . Delaware River Iron Ship Building Works, Chester, Pa. '84
*Gay, Harry S., . . . . . Lykens, Pa. '85
*Gayley, James, . . . . . Braddock, Pa. '80
†Gazzam, Joseph P., . . . . 2810 Pine Street, St. Louis, Mo. '84
*Genth, F. A., Jr., . . . 4014 Chestnut Street, W. Philadelphia. '77
*George, Richard, . . . . . Dover, N. J. '75
*George, S. W., . . . . . Chester, N. J. '84
*George, W. R., . . . . . Dover, N. J. '81
†Gibb, Frank W., . . . . . Little Rock, Ark. '82
*Gibson, C. H., . . . . . Lock Box 1705, New York City. '82
*Gilbert, Edward G., . . . . . Troy, N. Y. '83
*Gill, John L., Jr., . . . . 2 Woodland Terrace. Philadelphia. '76
†Gillespie, T. A., . . . . . Pittsburgh, Pa. '86
*Gilpin, Edwin, Jr., . . . . . Halifax, Nova Scotia. '85
*Gladwin, F. E., . Care Dr. F. C. E. Mueller, El Plomo, Sonora, Mexico. '84
*Glenn, William, . . . . . South Strafford, Vermont. '81
*Goetz, George W., . . . Otis Iron and Steel Co., Cleveland, Ohio. '82
*Going, Charles B., . . . . . Cincinnati, Ohio. '83
*Goodale, Charles W., . . . . . Butte City, Montana. '76
†Goodwin, H. Stanley, . . . . . Bethlehem, Pa. '71
*Gordon, Alexander, . . . . . Hamilton, Ohio. '84
*Gordon, Fred W., . . . . 226 Walnut Street, Philadelphia. '80
*Gorham, Austin G., . . . . . 35 Wall Street, New York City. '81
†Gorton, Frank S., . . . . Chicago Forging Co., Chicago, Ill. '84
*Gosling, Edgar B., . . 406 W. Seventy-third Street, New York City. '83
†Gowen, Franklin B., . . . 119 N. Fourth Street, Philadelphia. '72
*Graham, Frank, . . . P. O. Box 280, Georgetown, Colorado. '84
*Graham, John, Jr., . . . Camden Iron Works, Camden, N. J. '83
†Graham, Thomas, . . . . 233 S. Third Street, Philadelphia. '75
*Graham, Thomas H., . . . . 400 Chestnut Street, Philadelphia. '81
†Green, Edward M., . . . . . Troy, N. Y. '83
*Gridley, Edward, . . . . . Wassaic, Dutchess Co., N. Y. '77
*Griffen, George S., . . . . . Phœnixville, Pa. '80
**Griffen, H. M., . . . . . Georgetown, Colorado. '82
†Griffiths, Howard B., . . . 2327 Ridge Avenue, Philadelphia. '77
*Griscom, Samuel E., . . . . 324 N. Eighth Street, Philadelphia. '76
*Griswold, Chester, . . . . . 11 Pine Street, New York City. '79
*Griswold, Francis B., . . . . . Troy, N. Y. '83
*Griswold, J. Wool, . . . . . Troy, N. Y. '83
*Grittinger, Henry C., . . . . Cornwall, Lebanon Co., Pa. '79
*Groesbeck, J. D., . . . . P. O. Box 96, Tombstone, Arizona. '82
*Gross, Henry S., . . . . 119 Market Street, Harrisburg, Pa. '81
*Gross, Louis N., . . . . . Box 411, Deadwood, Dakota. '85
*Grothe, A., . . . . . P. O. Box 4, Guanajuato, Mexico. '86
*Grove, John H., . . . . . Danville, Pa. '80
*Gubley, William, . . . . . Troy, N. Y. '83

*Habirshaw, W. M., . . . . 159 Front Street, New York City. '84

*Hackett, William H., . . . . 92 Puelian Street, Atlanta, Ga. '81
*Hackney, Herbert, . . . . . Portland, Oregon. '83
*Hadley, Walter C., . . . . . Silver City, N. M. '83
*Hagerman, J. J., . . . . Colorado Springs, Colo. '75
*Hague, Arnold, . . . . . University Club, New York City. '74
*Hahn, Albert G. C., . . . . 180 Baltic Street, Brooklyn, N. Y. '85
*Hahn, Ignatius, . P. O. Box 155, Sharpsburg, Allegheny Co., Pa. '79
**Hahn, O. H., . . . . P. O. Box 8, South Pueblo, Colorado. '71
*Haines, Reuben, . 123 West Chelten Ave., Germantown, Philadelphia. '82
*Halberstadt, Baird, . . . . . Pottsville, Pa. '84
*Hale, Prof. Albert C., . . . . P. O. Box 65, Brooklyn, N. Y. '82
*Hale, Albert W., . . . . . 1 Broadway, New York City. '75
*Hall, C. C., . . . . . 313 Iron Street, S. St. Louis, Mo. '82
*Hall, Edward J., Jr., . . . 15 Cortlandt Street, New York City. '76
*Hall, Robert W., . . . 3 W. Fifty-sixth Street, New York City. '76
*Halsey, Fred A., . . . . . 23 Park Place, New York City. '82
*Hamilton, Alexander, . . . . Drawer PP., Johnstown, Pa. '78
*Hamilton, William G., . . . . 24 West Street, New York City. '76
*Hammond, Charles L., . . . . 40 S. Clark Street, Chicago, Ill. '78
*Hammond, John Hays, . . . 35 Wall Street, New York City. '81
*Hammond, W. B., . . . . . Deadwood, Dakota. '83
*Harden, E. B., . . . . 537 N. Thirty-third Street, Philadelphia. '73
*Harden, J. H., . . . . . Phœnixville, Pa. '71
*Hardman, John E., . . . . Oldham Gold Mines, Nova Scotia. '82
*Harker, O. H., . . . . . Leadville, Colorado. '82
*Harnickell, A., . . . P. O. Box 2503, New York City. '74
*Harrington, Dr. B. J., . . . McGill College, Montreal, Canada. '77
*Harris, Joseph S., . . . . 226 S. Third Street, Philadelphia. '72
*Harris, O. D., . . . . . Ste. Genevieve, Mo. '84
*Harris, W. J., . . . . . Hazleton, Pa. '71
*Harrison, Russell B., Superintendent U. S. Assay Office, Helena, Montana. '77
*Hart, Prof. Edward, . . . . . Lafayette College, Easton, Pa. '81
†Hart, William R., . . . . 224 S. Third Street, Philadelphia. '77
*Hartmann, A., . . . . . Belleville, Ill. '86
*Hartman, John M., . . . 1235 N. Front Street, Philadelphia. '75
*Hartranft, S. S., . . . , Public Buildings, Philadelphia. '77
*Hartshorne, J., . . . . Care Pottstown Iron Co., Pottstown, Pa. '73
*Harty, William, . . . . P. O. Box 207, Portsmouth, Ohio. '79
†Harvey, William H., . Commonwealth Iron Co., Cleveland, Ohio. '80
*Hassinger, W. H., . . . . . Youngstown, Ohio. '86
*Hastings, Robert E., . . . 819 Filbert Street, Philadelphia. '84
*Haws, H. Y., . . . . . Johnstown, Pa. '81
*Hayden, Dr. F. V., . . . . 1805 Arch Street, Philadelphia. '81
*Haydon, J. C., . . . . . Jeansville, Luzerne Co., Pa. '74
*Hayward, A. A., . . . . Renfrew Gold Mines, Nova Scotia. '85
*Heard, John, . . . Care Aug. Heard, 39 Nassau Street, N. Y. '83
*Hearne, Frank J., . . . . . Wheeling, West Va. '74
*Heartt, Jonas S., . . . . . Troy, N. Y. '83
*Heberlein, A., . . . . . Butte City, Montana. '85
*Heckscher, A., . . . . . 47 N. Front Street, Philadelphia. '79

| | | |
|---|---|---|
| *Hegeler, Edward C., | La Salle, Ill. | '81 |
| *Hemenway, E. P., | 39 John Street, New York City. | '81 |
| *Hemphill, James, | Twelfth and Pike Streets, Pittsburgh, Pa. | '75 |
| *Henderson, C. Hanford, | 361 Broadway, N. Y. | '83 |
| *Henning, Gus. C., | 18 Cedar Street, New York. | '86 |
| *Henrich, Carl, | Noble, Richland Co., Ill. | '82 |
| **Herndon, Edward L., | Care H. Ames & Co., St. Louis, Mo. | '82 |
| *Herr, Danl. C., | 305 Walnut Street, Harrisburg, Pa. | '85 |
| *Herr, H. B., | P. O. Drawer 132, Chicago, Ill. | '76 |
| *Herrick, J. A., | 6 Crosby Square, Bishopgate Street, London, Eng. | '76 |
| *Hewett, G. C., | Jenkintown, Montgomery Co., Pa. | '83 |
| *Hewitt, Abram S., | 17 Burling Slip, New York City. | '71 |
| *Hewitt, George H., | Aspen, Colorado. | '80 |
| *Hibbard, Henry D., | West Roxbury, Mass. | '79 |
| *Hibbs, James M., | 1330 Buttonwood Street, Philadelphia. | '83 |
| †Hickox, Charles V., | 175 Dearborn Street, Chicago, Ill. | '84 |
| †Hildreth, R. W., | 25 Madison Ave., New York City. | '85 |
| †Hildreth, Walter E., | 52 Broadway, New York City. | '75 |
| *Hill, Frank A., | 1600 Arch Street, Philadelphia. | '83 |
| *Hill, Jesse T., | Chattanooga, Tenn. | '85 |
| †Himrod, Charles, | 186 Dearborn Street, Chicago, Ill. | '85 |
| **Hinchman, Charles S., | 208 S. Fourth Street, Philadelphia. | '79 |
| *Hitchcock, Prof. C. H., | State Geologist, Hanover, N. H. | '79 |
| *Hitchcock, E. A., | Crystal Plate Glass Co., St. Louis, Mo. | '80 |
| *Hoatson, Thomas, | Calumet, Michigan. | '80 |
| *Hock, O., | Isbergues, P. de C., France. | '86 |
| *Hodges, A. D., Jr., | P. O. Box 1857, Boston, Mass. | '84 |
| *Hodgson, Thos., | Washington Street, Buffalo, N. Y. | '85 |
| *Hoffman, E. O., | Care Barney & Smith M'f'g Co., Dayton, O. | '84 |
| *Hoffman, John W., | 208 S. Fourth Street, Philadelphia. | '76 |
| *Hoffmann, Ottokar, | N. Mex. Mining Co., Cusihuiriachic, Chihuahua, Mex. | '84 |
| *Hofman, H. O., | 2102 Mt. Vernon Street, Philadelphia. | '82 |
| *Hoffstott, F. N., | P. O. Box 177, Pittsburgh, Pa. | '82 |
| *Holbrook, F. N., | El Paso, Texas. | '75 |
| †Holbrook, Levi, | P. O. Box 536, New York City. | '78 |
| *Hollenbeck, J. I., | Audenried, Carbon Co., Pa. | '82 |
| *Hollerith, Herman, | 617 Seventh Street, Washington, D. C. | '83 |
| *Hollis, H. L., | Braddock, Pa. | '85 |
| *Holloway, J. F., | Detroit and Center Streets, Cleveland, Ohio. | '75 |
| *Holman, F. C., | Care E. W. Burr, Polk and Filbert Sts., San Francisco, Cal. | '81 |
| †Holt, George H., | Crested Butte, Gunnison Co., Colorado. | '82 |
| *Hooker, W. A., | 2 Wall Street, New York City. | '80 |
| *Hooper, William, | Ticonderoga, N. Y. | '78 |
| *Hotchkiss, Jed., | Staunton, Va. | '79 |
| *Houston, C. B., | Thurlow, Delaware Co., Pa. | '83 |
| *Houston, T. J., | Thurlow, Delaware Co., Pa. | '82 |
| *Howald, Ferdinand, | Fire Creek, Fayette Co., W. Va. | '84 |
| †Howard, L. I., | St. Louis, Mo. | '86 |
| †Howe, Epenetus, | North Salem, Westchester Co., N. Y. | '86 |
| *Howe, Frank P., | Danville, Pa. | '79 |

*Howe, Henry G., . . . . P. O. Box 196, Tombstone, Arizona. '83
*Howe, Henry M., . . . . . Hotel Oxford, Boston, Mass. '71
*Howell, Benjamin P., . . . . . Scottdale, Pa. '84
*Howland, Andrew B., . . . . . Box 403, Titusville, Pa. '86
*Huber, H., . . . . . Kelly, N. M. '82
*Huhn, E. C. O., . . . . . Providence, Cal. '86
†Hulbert, Thomas H., . . . . . Middletown, Conn. '81
†Hulick, William H., . . . . . Easton, Pa. '82
*Hulst, Nelson P., . . . . 300 Knapp Street, Milwaukee, Wis. '76
*Humbert, William S., . . . P. O. Box 431, Sing Sing, N. Y. '83
*Humphrey, Chas., . . . . . Carlisle, N. M., via Lordsburg. '85
*Humphrey, D. W., . . . . 902 Cedar Avenue, Scranton, Pa. '82
*Humphrey, George S., . . . . . Ithaca, N. Y. '84
*Humphreys, Alex. C., . . . 333 Walnut Street, Philadelphia. '85
*Humphreys, A. W., . . . . 45 William Street, New York City. '72
*Hungerford, W. S., . . . . . Low Moor, Va. '82
†Hunicke, Aug, . . . . Washington University, St. Louis, Mo. '83
*Hunt, Alfred E., . . . . 98 Fourth Avenue, Pittsburgh, Pa. '79
*Hunt, Fred. F., . . . . . New Brighton, S. I., N. Y. '80
*Hunt, Joseph, . . . . . Catasauqua, Pa. '71
*Hunt, Joshua, . . . . . Catasauqua, Pa. '78
*Hunt, Robert W., Albany and Rensselaer Iron and Steel Co., Troy, N. Y. '74
*Hunt, Dr. T. Sterry, . . . . . Montreal, Canada. '71
†Huntington, Fred. W., . . 109 S. Oxford Street, Brooklyn, N. Y. '85
*Hutchinson, E. S., . . . . . Newtown, Pa. '80
*Hutter, E. S., . . . . . Houston Mines, Botetourt Co., Va. '83
*Hutton, Fred. R., . . . 6 W. Thirty-third Street, New York City. '75
*Hutton, William R., . . . . 35 Broadway, New York City. '82

*Ihlseng, Axel O., . . . . . Golden, Colorado. '82
†Ingham, William A., . . . 320 Walnut Street, Philadelphia. '72
*Inman, Alvin L., . . . . . Plattsburgh, N. Y. '76
*Irving, Prof. Roland D., . . University of Wisconsin, Madison, Wis. '72
†Irwin, John H., . . . . . Morton, Delaware Co., Pa. '81

*Jackson, Edward F., . . . 3706 Washington Avenue, St. Louis, Mo. '83
*James, Isaac E., . . . . . Duncan, Arizona. '82
*James, Reese, . . . . . South Pueblo, Colorado. '79
*James, Samuel, Jr., . . . . . Rico, Colorado. '76
†James, Dr. Walter M., . . 1123 Spruce Street, Philadelphia, Pa. '84
†James, William, . . . . . St. James, Phelps Co., Mo. '82
*Jamme, George, . . Dayton Coal and Iron Co., Limited, Dayton, Tenn. '79
†Janeway, John H., . . . . . Governors Island, N. Y. '86
*Janin, Alexis, . . . . . 610 Hyde Street, San Francisco, Cal. '85
*Janin, Henry, . . . . . 12 Fifth Avenue, New York City. '72
*Janin, Louis, . . 211 Sansome Street, Room 6, San Francisco, Cal. '72
*Janney, Morris P., . . . . . Pottstown, Pa. '74
†Jarvis, W. F., . . . . . 34 Campan Building, Detroit, Mich. '84
*Jenney, Walter P., . . . . . Box 283, Hailey, Idaho. '74

| | | |
|---|---|---|
| *Jennings, E. P., | Sterlington, Rockland Co., N. Y. | '76 |
| *Jennings, Hennen, | Quicksilver Mining Co., New Almaden, Cal. | '84 |
| *Jennings, W. H., | C. H. V. & T. Railway, Columbus, O. | '84 |
| *Jeter, J. Tinsley, | Wilkesbarre, Pa. | '84 |
| *Jewell, Edward E., | Calumet I. & S. Co., Cummings, Ill. | '84 |
| *Jewett, Eliot C., | U. S. Assay Office, St. Louis, Mo. | '81 |
| *Johns, L. W., | Pratt Mines, Jefferon Co., Ala. | '85 |
| *Johnson, Lieut. D. D., | Fort Monroe, Va. | '82 |
| *Johnson, Isaac G., | Spuyten Duyvil, New York City. | '79 |
| *Johnson, J. E., | Longdale, Alleghany Co., Va. | '80 |
| *Johnson, W. G., | Pine Grove, Pa. | '84 |
| *Johnston, A. B., | Birmingham, Ala. | '86 |
| *Johnston, James, | 417 Straight Street, Paterson, N. J. | '85 |
| *Johnston, Walter N., | Buchanan, Botetourt Co., Va. | '81 |
| *Jolliffe, William, | Lexington, Va. | '81 |
| *Jones, B. F., | Jones & Laughlin's Works, Pittsburgh, Pa. | '78 |
| *Jones, D. N., | Colorado Coal and Iron Co., Bessemer, Colorado. | '75 |
| *Jones, Griffith, | Pottstown, Pa. | '81 |
| *Jones, John T., | Iron River Furnace Co., Iron River, Mich. | '80 |
| *Jones, R. R., | 107 Dearborn Street, Chicago, Ill. | '82 |
| *Jones, T. Catesby, | Va. Nail & Iron Works, Lynchburg, Va. | '81 |
| *Jones, Thomas D., | Ebervale, Pa. | '75 |
| †Jones, Thomas D., | 99 Randolph Street, Chicago, Ill. | '84 |
| *Jones, W. R., | Braddock, Pa. | '75 |
| **Jones, Washington, | 1632 N. Fifteenth Street, Philadelphia. | '81 |
| *Jopling, Jas. E., | Marquette, Mich. | '84 |
| *Joüet, C. H., | Roselle, N. J. | '83 |
| *Judson, Jno. N., | 2201 Park Ave., St. Louis, Mo. | '84 |
| †Julian, Frank, | Union Steel Co., 31st St. and Ashland Ave., Chicago, Ill. | '81 |

| | | |
|---|---|---|
| *Kaercher, Edw. E., | Shamokin, Pa. | '84 |
| *Kaufman, William M., | Reading, Pa. | '84 |
| *Karrick, L. C., | Salt Lake City, Utah. | '86 |
| *Kay, Prof. Edgar B., | 18 Fourth Street, Troy, N. Y. | '83 |
| *Kebler, Eliot A., | 91 Fifth Avenue, Pittsburgh, Pa. | '84 |
| *Kebler, Julian A., | Ottumwa, Iowa. | '85 |
| *Keeley, Jerome, | 206 Walnut Place, Philadelphia. | '76 |
| *Keen, Barton L., | 175 Dearborn Street, Chicago, Ill. | '84 |
| †Keith, H. A., | Chicago, Ill. | '84 |
| *Keller, Arthur H., | P. O. Box 48, Silverton, Colorado. | '83 |
| *Keller, Hermann A., | P. O. Box 267, Leadville, Colorado. | '81 |
| *Kemp, William, | Troy, N. Y. | '83 |
| *Kempton, C. W., | 61 Broadway, New York City. | '75 |
| *Kennedy, Hugh, | Etna, Allegheny Co., Pa. | '81 |
| *Kennedy, John S., | Lock Box 5, Steelton, Dauphin Co., Pa. | '81 |
| *Kennedy, Julian, | Lilly Furnace Co., Pittsburgh, Pa. | '79 |
| *Kent, Joseph C., | Phillipsburg, N. J. | '72 |
| *Kent, R., | Standard Steel Works, Lewistown, Pa. | '84 |
| *Kent, William St. G., | Phœnixvillle, Pa. | '72 |
| *Kent, William, | 26 Highland Avenue, Jersey City, N. J. | '76 |

†KERR, THOMAS B., . . . . 110 Diamond Street, Pittsburgh, Pa. '82
*KEYES, W. S., . . . . . P. O. Box 1716, San Francisco, Cal. '72
*KIDDIE, THOMAS, . P. O. Box 44, New Brighton, Staten Island, N. Y. '82
*KIMBALL, HIRAM, . . . . . City Forge, Cleveland, Ohio. '82
*KIMBALL, DR. J. P., . . . . Lehigh University, Bethlehem, Pa. '72
*KINEALY, JAMES R., . . . . . Baden, St. Louis City, Mo. '83
**KING, CHARLES F., . . . . . Steelton, Dauphin Co., Pa. '80
*KING, DANIEL, . . . Pine Grove Furnace, Cumberland Co., Pa. '81
*KING, FRANK, . . . Van Buren Furnace, Shenandoah Co., Va. '81
†KING, J. H., . . . . . Painesville, Lake Co., Ohio. '80
*KING, THOMAS M., . . . . . B. & O. R. R., Pittsburgh, Pa. '82
*KINGSLEY, J. COOK, . . . . . P. O. Box 48, Silverton, Colorado. '82
*KINKEAD, MAX, . . . . . Altoona, Pa. '82
†KIRBY, EDMUND B., . Oregon Avenue and Juniata Street, St Louis, Mo. '84
*KIRCHHOFF, CHARLES, JR., . . . . . 66 Duane Street, N. Y. '75
*KLEPETKO, FRANK, . . . . . Opechee, Houghton Co., Mich. '80
*KNAP, JAMES G., . . . . . Ogdensburgh, N. Y. '80
*KNAP, JOSEPH M., . . . . . 365 West Street, New York City. '81
†KNAPP, S. A., JR., . . . . . Hawthorne, Nevada. '85
*KNIGHT, ALBERT B., . . . . . Butte City, Montana. '84
*KNIGHT, E., . . . . . Albany Iron Works, Troy, N. Y. '83
*KNORR, A. E., . . . . 1344 R Street, N. W., Washington, D. C. '83
*KNOX, JOHN H., . . . . . Lebanon, Hunterdon Co., N. J. '80
*KOENIG, PROF. GEORGE A., University of Pennsylvania, W. Philadelphia. '74
*KRIETE, HENRY C., . . . . 17 Metropolitan Block, Chicago, Ill. '84
*KROM, S. R., . . . . . 93 Washington Street, New York City. '85
*KUNHARDT, WHEATON B., . . . . 35 Broadway, New York City. '80

†LACOMBE, CHAS. F., . . . Care E. H. Lacombe, Morristown, N. J. '85
†LAMBERTON, WILLIAM B., . . 216 Market Street, Harrisburg, Pa. '83
*LAMBORN, DR. ROBERT H., . . . 32 Nassau Street, New York City. '76
*LANE, J. S., . . . . . 199 Lake Street, Chicago, Ill. '80
**LANDIS, EDWARD K., . . 264 S. Thirty-eighth Street, Philadelphia. '82
*LANDSBERG, E., . . . . . Aachen, Germany. '83
*LANGDON, N. M., . . . . . Paxton Furnace, Harrisburg, Pa. '81
*LARSSON, PER., . . . . . Iron Mountain, Mich. '86
*LATHROP, W. A., . . . . . Snowshoe, Center Co., Pa. '83
*LAUDER, GEORGE, . . . . . 48 Fifth Avenue, Pittsburgh, Pa. '78
*LAUREAU, L. G., . . . . 226 Walnut Street, Philadelphia, Pa. '78
*LAVAGNINO, G., . . . . . Box 550, Salt Lake City, Utah. '85
*LAWRENCE, BENJAMIN B., . . . Montezuma, Summit Co., Colorado. '82
*LAWRENCE, W. L., . . . . . Burden, Columbia Co., N. Y. '83
*LAWSON, GEORGE, . . . . . Halifax, Nova Scotia. '85
†LEARY, DANIEL J., . . . . 138 Keap Street, Brooklyn, N. Y. '81
*LEAVENS, H. W., . . . . . Salt Lake City, Utah. '85
*LEAVITT, E. D., JR., . . . 604 Main Street, Cambridgeport, Mass. '76
†LE BARON, J. FRANCIS, . . . . . Jacksonville, Fla. '84
*LECKIE, ROBERT G., . . . . . Sherbrooke, Quebec, Canada. '79
†LEE, GEO. B., . . . . . Care W. H. Lee, Minneapolis, Minn. '85
*LEE, R. H., . . . . . Lewistown, Pa. '76

| | | |
|---|---|---|
| *Lee, R. H., Jr., | Lewistown, Pa. | '83 |
| *Lee, Richard Henry, | Duluth, Minn. | '76 |
| *Leggett, Thomas H., | Care N. Y. & Honduras Rosario Mining Co., San Juancito, Honduras, C. A., via Colon. | '82 |
| *Lehman, A. E., | 711 Walnut Street, Philadelphia. | '83 |
| †Lehman, F. L., | 99 John Street, New York City. | '82 |
| *Leisenring, E. B., | Mauch Chunk, Carbon Co., Pa. | '82 |
| *Leith, Alexander J., | 11 Pine Street, New York City. | '79 |
| *Lennig, Nicholas, | 112 S. Front Street, Philadelphia. | '82 |
| *Lentz, W. O., | Mauch Chunk, Pa. | '85 |
| *Lesley, Prof. J. P., | State Geologist, 1008 Clinton Street, Philadelphia. | '71 |
| *Lewis, David B., | Box 790, Yonkers, N. Y. | '81 |
| *Lewis, James B., | Dover, N. J. | '75 |
| *Lewis, James F., | 23 Park Place, New York City. | '75 |
| †Lewis, Samuel W., | 7 Nassau Street, New York City. | '82 |
| *Lilienberg, N., | 150 Broadway, New York City. | '84 |
| *Lilly, William, | Mauch Chunk, Pa. | '79 |
| *Lincoln, Charles J., | High School, East Boston Mass. | '83 |
| *Lincoln, G. Russell, | Pottstown Iron Co., Pottstown, Pa. | '79 |
| *Lindsley, Stuart, | Orange, N. J. | '82 |
| *Lippincott, J. Evans, | Mt. Auburn, Cincinnati, Ohio. | '85 |
| *Little, Frank J., | North Chicago Rolling Mill Co., S. Chicago, Ill. | '84 |
| *Livingston, Herman, | Catskill Station, Columbia Co., N. Y. | '82 |
| *Lobanoff, Paul F., | 277 Lasalle Avenue, Chicago, Ill. | '83 |
| *Lodge, Richard W., | 1423 Washington Street, Boston, Mass. | '83 |
| †Logan, John P., | 319 Walnut Street, Philadelphia. | '83 |
| *Loiseau, E. F., | 65 rue de la Victoire, Brussels. | '73 |
| *Loiseau, Oscar, | Ougrée, Belgium. | '82 |
| *Lombard, Thos. R., | 140 Nassau Street, New York City. | '86 |
| *Long, John C., | Mechanicsburg, Pa. | '81 |
| *Long, William H., | Fairlee, Vermont. | '82 |
| *Longacre, Orleans, | 141 Centre Street, New York City. | '81 |
| *Longnecker, G. A., | Mechanicsburg, Pa. | '83 |
| *Lord, Prof. N. W., | Ohio State University, Columbus, Ohio. | '75 |
| *Lovejoy, Ellis, | 721 E. Broad Street, Columbus, Ohio. | '86 |
| †Luce, Edward M., | Milwaukee, Wis. | '84 |
| †Ludlam, Joseph S., | Lowell, Mass. | '81 |
| *Lukens, Jawood E., | Conshohocken, Pa. | '84 |
| †Lunn, Maurice J., | Lewis Block, Pittsburgh, Pa. | '84 |
| *Luther, Henry M., | Ashland, Pa. | '84 |
| *Luther, R. C., | Pottsville, Pa. | '84 |
| *Lutscher, Gaudenz, | 6 Worswick Court, Cleveland, Ohio. | '85 |
| *Luttgen, Eberhard, | Care Keasbey & Mattison, Ambler, Pa. | '85 |
| **Lyman, Benjamin Smith, | Northampton, Mass. | '71 |
| †Lyman, Frank, | 130 Water Street, New York City. | '77 |
| †McCallum, Wm. H., | New Glen Echo Mills, Wayne Junction, Philadelphia. | '84 |
| *McCandless, E. V., | Pittsburgh, Pa. | '79 |
| *McCarty, Dennis, | Tombstone, Arizona. | '85 |
| *McCay, Dr. L. W., | Princeton College, Princeton, N. J. | '85 |

*McClellan, Arthur, . . . . . Drifton, Luzerne Co., Pa. '71
*McClure, Robert J., . . . . C. B. & Q. R. R. Co., Chicago, Ill. '84
*McComb, A. M., . . . . . 233 Central Avenue, Dayton, Ohio. '80
*McCormick, Henry, . . . . . Harrisburg, Pa. '74
*McCreath, Andrew S., . . . 223 Market Street, Harrisburg, Pa. '75
*McCulloch, E. A., . . . . P. O. Box 2346, New York City. '80
*McDermott, Walter, . . . . 2 Wall Street, New York City. '74
*McDonald, Saml., . . . . . Benwood, W. Va. '85
*McDowell, Frederick H., . . 120 Liberty Street, New York City. '78
†McElmell, Thomas A., . . . Keams Cañon, Apache Co., Arizona. '82
*McFadyen, John, . . . . . Johnstown, Pa. '78
*McGenniss, J. W., Jr., North Chicago Rolling Mill Co., South Chicago, Ill. '85
*McGuffin, J. A., . . Sewell Depot, C. & O. Ry., Fayette Co., Va. '81
†McIlvain, E. M., . . . . . Reading, Pa. '86
†McIntosh, William A., . . . 41 Fifth Avenue, Pittsburgh, Pa. '79
†McKenzie, Dr. John C., . 328 Montgomery Street, San Francisco, Cal. '82
*McKeown, S. W., . . . . . Youngstown, Ohio. '83
*McLanahan, J. King, . . . . . Hollidaysburg, Pa '81
*McLeavy, John, . . . . . Punxsutawney, Pa. '75
*McLennan, J. S., . . . . . Sydney, Cape Breton, N. S. '85
*McLeod, H. S., . . . . . Troy, N. Y. '83
*McMillan, Prof. Chas., . . . . . Princeton, N. J. '84
*McNair, Thomas S., . . . . . Hazleton Pa. '71
*McRoberts, J. H., . . . . 400 Grant Street, Pittsburgh, Pa. '86
*Macdonald, Charles, . . . . 18 Broadway, New York City. '75
*Macfarlane, G., . . . . . Peerless, Kanawha Co., W. Va. '86
*Mackintosh, James B., . . . 55 Garden Street, Hoboken, N. J. '76
*MacLean, . . . . 1317 Vermont Avenue, Washington, D. C. '86
*MacTeague, J. J., . . . . . 635 Lexington Avenue, N. Y. '85
*Macy, Arthur, . . . . . Silver King, Arizona. '76
*Maffet, W. R., . . . . . Wilkes-Barre, Pa. '74
*Mahon, Prof. R. W., . . . . 110 Arch Street, Camden, N. J. '83
*Male, John, . . . . . Troy, N. Y. '83
*Malo, Alberto, . . Puente de Santa Afia, City of Mexico, Mex. '85
*March, William J., . . . . Ribon & March, Jersey City, N. J. '80
†Marié, Leon, . . . 48 West Nineteenth Street, New York City. '85
*Markham, Alfred, . . . . . Markhamville, N. B., Canada. '82
*Markle, Alvan, . . . . . Hazleton, Pa. '85
*Markle, John, . . . . . Jeddo, Luzerne Co., Pa. '79
*Marple, William M., . . . . . Scranton, Pa. '81
*Mars, John H., . . . . . Albany, N. Y. '81
*Marshall, Charles A., . . . . P. O. Box 766, Johnstown, Pa. '82
**Martin, E. P., . . . . . Dowlais, Glamorgan, Wales. '81
*Martin, Edw. W., . Fifty-seventh Street and Broadway, New York City. '85
*Martin, J. B., . . . . . Steelton, Pa. '86
*Martin, R. L., . . . . . Fairchance, Fayette Co., Pa. '81
*Martine, Charles A., . . . . . Georgetown, Colorado. '79
*Marvin, Selden E., . . . . . Albany, N. Y. '78
*Mason, Prof. William P., . . . . . Troy, N. Y. '83
*Masters, W. U., . . . . . Cleveland, Ohio. '79

| | | |
|---|---|---|
| *Mather, Samuel, | 101½ Water Street, Cleveland, Ohio. | '79 |
| †Mather, W. G., | Cleveland, Ohio. | '86 |
| *Matherson, W. G., | New Glasgow, N. S. | '85 |
| *Mathias, D. S., | P. O. Box 497, South Chicago, Ill. | '86 |
| *Mathieu, Jean A., | North-East, Cecil Co., Md. | '82 |
| *Mattes, W. F., | Scranton, Pa. | '81 |
| *Matthiessen, F. W., | Lasalle, Ill. | '84 |
| *Maury, M. F., | Avondale, Cincinnati, Ohio. | '74 |
| *Maxon, John H., | 2305 Washington Avenue, St. Louis, Mo. | '74 |
| *Maxwell, J. R., | Hamilton, Ohio. | '84 |
| *Maxwell, J. W., | 3 Holland Street, Syracuse, N. Y. | '81 |
| *May, De Courcey, | 1230 Spruce Street, Philadelphia. | '79 |
| *Maynard, George W., | 35 Broadway, New York City. | '71 |
| *Mayo, James H., | 1 Broadway, New York City. | '82 |
| *Meade, Spencer, | N. Central Railway Co., Elmira, N. Y. | '81 |
| †Means, Archibald, | Peru, La Salle Co., Ill. | '82 |
| *Meier, Edward D., | 102 N. Main Street, St. Louis, Mo. | '86 |
| *Meier, John W., | 102 N. Main Street, St. Louis, Mo. | '74 |
| *Meigs, H. V. L., | Lebanon, Pa. | '86 |
| †Meigs, Prof. John, | Pottstown, Pa. | '81 |
| *Meister, Herman, | 3013 Maramec Street, Station B, St. Louis, Mo. | '77 |
| *Mercur, Frederick, | Wilkes-Barre, Pa. | '71 |
| *Merriam, W. N., | 314 Langdon Street, Madison, Wis. | |
| †Merrill, F. J. H., | 126 E. Sixtieth Street, New York City. | '85 |
| *Merritt, William Hamilton, | 15 Toronto Street, Toronto, Canada. | '79 |
| †Merryweather, George, | 94 Dearborn Street, Chicago, Ill. | '80 |
| *Metcalf, O., | Lock Box 1784, Colorado Springs, Colorado. | '79 |
| *Metcalf, William, | Pittsburgh, Pa. | '75 |
| *Meyer, Carl, | Limburg, a. d. L., Germany. | '83 |
| *Michaelis, Capt. O. E., | Watervliet Arsenal, W. Troy, N. Y. | '82 |
| *Mickley, Edwin, | Hokendauqua, Pa. | '74 |
| *Miller, Charles W., | P. O. Box 401, Aspen, Colorado. | '84 |
| *Miller, George S., | Care Laughlin and Junction Steel Co., Mingo Junction, Ohio. | '85 |
| *Miller, Horace B., | 96 Fulton Street, New York City. | '81 |
| *Miller, Reuben, | Pittsburgh, Pa. | '75 |
| *Milliken, George F., | Room 27, 120 Broadway, New York City. | '79 |
| *Mills, Frank P., | 214 Thirty-first Street, Chicago, Ill. | '83 |
| *Mills, James E., | Quincy, Plumas Co., Cal. | '77 |
| *Mitchener, Chas. E., | Stockton, Utah. | '86 |
| *Moen, Philip W., | Worcester, Mass. | '82 |
| *Moffat, E. S., | Scranton, Pa. | '71 |
| *Monell, Joseph T., | 1305 S. Eighth Street, St. Louis, Mo. | '81 |
| *Moore, Charles J., | P. O. Box 1247, Leadville, Colorado. | '82 |
| *Moore, James, | Sixteenth and Buttonwood Streets, Philadelphia. | '75 |
| *Moore, Lycurgus B., | 96 Fulton Street, New York City. | '81 |
| *Moore, Marshall G., | Johnstown, Pa. | '86 |
| *Moore, Philip N., | Olympia, Bath Co., Ky. | '74 |
| †Moore, William P., | 172 Bank Street, Norfolk, Va. | '83 |
| *Morgan, Charles H., | Worcester, Mass. | '74 |

*Morgan, James, . . . . 2528 Sarah Street, Pittsburgh, Pa. '79
*Morgan, Joseph, Jr., . . . . . Johnstown, Pa. '81
*Morgan, T. R., . . . . . Alliance, Ohio. '78
*Morison, George S., . . . . . 35 Wall Street, New York City. '79
*Morrell, T. T., . . . . . Cambria Iron Co., Johnstown, Pa. '79
*Morris, Henry G., . . . . . 209 S. Third Street, Philadelphia. '84
†Morris, Israel W., . . . . . 228 S. Third Street, Philadelphia. '75
*Morris, S. Fisher, . . . . . Box 790, Yonkers, N. Y. '74
**Morris, William H., . . . . 400 Chestnut Street, Philadelphia. '81
*Morse, H. G., . . . . . Youngstown, Ohio. '81
*Morse, Jay C., . . 302 First National Bank Building, Cleveland, Ohio. '80
*Morse, Philip S., . . . . . P. O. Box 219, Pueblo, Colorado. '84
*Moses, Alfred J., . . . . . School of Mines, New York City. '82
*Moss, Prof. Milton, . . . . 413 Dearborn Avenue, Chicago, Ill. '82
*Moyer, Horace I., . . . . . Upper Lehigh, Pa. '82
*Mudd, Seeley W., . . . . . P. O. Box 489, Leadville, Colorado. '83
*Muhlenberg, N. H., . . . . . Lake Valley, New Mexico. '81
*Munroe, Prof. Henry S., . . . School of Mines, New York City. '72
*Munson, George C., . . . . . P. O. Box 2465, Denver, Colorado. '79
†Murdock, James H., 12 Bissel Bl'k, 7th Av. and Smithfield St., Pittsb'gh, Pa. '81
*Murray, George, . . . . . P. O. Box 211, Socorro, New Mexico. '82

*Nason, Prof. Henry B., . Rensselaer Polytechnic Institute, Troy, N. Y. '83
*Neale, Geo. F., . . . . . Crystal City, Mo. '85
*Neftel, Knight, . . . . . 32 Liberty Street, New York City. '81
*Neill, James W., . . . . . Mine La Motte, Madison Co., Mo. '79
*Neill, William L., . . . . . 201 Gravier Street, New Orleans, La. '80
*Neilson, James, . . . . . Youngstown, Ohio. '79
*Neilson, William G., . . . 3703 Chestnut Street, Philadelphia. '72
†Neustaedter, A., . . . . 2326 S. Eleventh Street, St. Louis, Mo. '86
*Newberry, W. E., . . . . . School of Mines, New York City. '85
*Newell, John E., . North Chicago Rolling Mill Co., S. Chicago, Ill. '84
*Nichols, Edward, . . . . . Hermitage, Ga. '73
**Nicholson, A. H., Care of Harriman & Co., Trinidad, British West Indies. '82
*Nicholson, Frank, . San Antonio, Sonora, Mexico, via Tucson, Arizona. '80
*Noble, Charles M., . . . . . Anniston, Alabama. '80
*Noble, Samuel E, . . . . . Anniston, Alabama. '81
*Noble, Stephen E., . . . . . Anniston, Alabama. '85
*Norris, R. Van A., . . . . . 36 Park Place, Newark, N. J. '85
*Northrop, John I., . . . . . School of Mines, New York City. '84
*Norton, F. O., . . . . . 92 Broadway, New York City. '82
*Norton, John M., . . . Jefferson Iron Works, Steubenville, Ohio. '86
*Norton, S., . . . . . Burden, N. Y. '85
*Norwood, Prof. Charles J., . . Bethel College, Russellville, Ky. '75
*Noyes, William, . . . . . Shafter, Presidio Co., Texas. '84
*Nye, Harold B., . North Chicago Rolling Mill Co., South Chicago, Ill. '85

*Oettinger, Dr. P. J., . . . . . Deming, New Mexico. '82
*Oglebay, Earl W., . . . . . Wheeling, W. Va. '80
*Olcott, E. E., . . . . . 10 Ceder Street, New York City. '74

*Olhausen, J. H., . . . . . Pottsville, Pa. '84
*Oliver, Henry W., Jr., . . Oliver Bros. & Phillips, Pittsburgh, Pa. '76
†Oliver, Gen. Paul A., . . . . . Wilkes-Barre, Pa. '71
†Oothout, E. Austin, . . . . 48 W. Ninth Street, New York City. '81
*Opperman, J. H., . . . . . Shawnee, Perry Co., Ohio. '80
*Ordway, Prof. J. M., . . Tulane University, New Orleans, La. '73
*Ormrod, George, . . . . . Emaus, Lehigh Co., Pa. '81
*Orton, Prof. Edward, . . . State University, Columbus, Ohio. '83
*Orton, Edward, Jr., . . . . . Buchtel, Ohio. '86
*Ostberg, Petter, . . . . . Stockholm, Sweden. '86
†Osterheld, T. W., . . . . . Yonkers, N. Y. '85
*Ostrander, F. A., . . . . . Troy, N. Y. '83
†Owen, J. R. D., . . . . . Newburg, Mo. '86
*Oxnard, B. A., . . . . Water and Dock Streets, Brooklyn, N. Y. '76

*Paddock, J. H., . . . . . St. Johnsbury, Vt. '82
*Page, George S., . . . . . Box 574, Braddock, Pa. '86
*Page, Walter Taylor, . Omaha & Grant S. & R. Co., Omaha, Neb. '82
*Page, William Byrd, . . . . . Leadville, Colorado. '77
*Page, William N., . . . . . Mt. Carbon, W. Va. '80
*Paine, Charles, . . . . . Pittsburgh, Pa. '86
†Painter, Augustus E. W., . . . J. Painter & Sons, Pittsburgh, Pa. '73
†Painter, William R., . . . . . Carrollton, Mo. '82
*Pardee, A., Jr., . . . . . 237 S. Third Street, Philadelphia. '75
*Pardee, I. P., . . . . . Stanhope, N. J. '73
*Park, William G., . . . . Park, Bro. & Co., Pittsburgh, Pa. '81
*Parker, Richard A., . . . . . Atlanta, Idaho. '82
*Parker, Russell, . . . . . 711 Pine Street, St. Louis, Mo. '82
*Parkes, John C., . . . . 17 Metropolitan Block, Chicago, Ill. '75
*Parkhurst, H. W., . . . . . Bristol, R. I. '82
*Parkin, Charles, . . . . . Pittsburgh, Pa. '75
*Parrott, Edward M., . Greenwood Iron Works, Orange Co., N. Y. '79
*Parrott, R. D. A., . . Greenwood Iron Works, Orange Co., N. Y. '79
†Parsons, Charles B., . . . Bonne Terre, St. François Co., Mo. '74
*Parsons, Charles O., . . . . 77 State Street, Boston, Mass. '74
*Patch, Maurice B., . . . . . Houghton, Mich. '83
*Patterson, J. C., . . . . . 4 Merrick Street, Philadelphia. '83
*Patterson, R. P., . . . . . Birdsboro, Pa. '86
*Payne, C. Q., . . Yale & Towne Manufacturing Co., Stamford, Conn. '81
†Peabody, Geo. F., . . . . 16 Broad Street, New York City. '85
**Pearce, Richard, . . . . . Argo, Colorado. '74
*Pearis, Charles F., . . . . . Gregory, Montana. '83
*Pearsall, H. D., . . . { Care of Mander Bros., Grace Church Street, London, England. '82
**Pearse, John B., . . . . . Roxbury, Mass. '72
**Pearson, John E., . . 59 Moffat-Kassler Block, Denver, Colorado. '82
*Pearson, John M., . . . . . Hudson, Columbia Co., N. Y. '82
*Pease, F. N., . . . . . P. O. Box 222, Altoona, Pa. '82
*Pechin, Edmund C., . . . . 122 Water Street, Cleveland, Ohio. '71
*Peckitt, Leonard, . . . . Reading Iron Works, Reading, Pa. '83

| | | |
|---|---|---|
| *Peele, R., Jr., | Silver King, Arizona. | '83 |
| *Penfield, Edw. W., | North Chicago Rolling Mill Co., South Chicago, Ill. | '86 |
| *Perkins, H. C., | El Callao Mining Co., Ciudad-Bolivar, Venezuela, via Port of Spain. | '81 |
| *Perry, Nelson W., | Oxford, Butler Co., Ohio. | '76 |
| *Perry, W. A., | 86 Liberty Street, New York City. | '83 |
| *Peters, E. D., Jr., | Box 332, Walpole, Mass. | '85 |
| *Peters, Richard, Jr., | Thurlow, Pa. | '84 |
| *Peters, Samuel, | Portland Rolling Mill, Portland, Maine. | '83 |
| *Pettee, Prof. William H., | University of Michigan, Ann Arbor, Mich. | '71 |
| *Pettigrew, Charles, | Joliet, Ill. | '84 |
| *Pettit, Robert E., | Altoona, Pa. | '81 |
| *Petre, Axel, | Midvale Steel Works, Nicetown, Philadelphia. | '83 |
| *Phillips, Enoch, | Radford, Pulaski Co., Va. | '83 |
| *Pierce, Frank M., | 10 Park Place, New York City. | '83 |
| *Pierce, H. N., | McCormick & Pierce, Washington, Iowa. | '84 |
| *Pierce, Willard Ide, | Care Hallam & Co., Honda, U. S. Columbia, C. A. | '77 |
| *Pillsbury, D. B., | Whiteside, Tenn. | '85 |
| *Pinkham, W. F., | Butte City, Montana. | '82 |
| *Pitcairn, Robert, | Pittsburgh, Pa. | '81 |
| *Pitman, Prof. S. M., | Lonsdale, R. I. | '73 |
| **Plater, John E., | Los Angeles, Cal. | '73 |
| *Platt, F. E., | 401 Fifth Avenue, New York City. | '81 |
| *Platt, Franklin, | 615 Walnut Street, Philadelphia. | '72 |
| *Platt, Joseph C., Jr., | P. O. Box 575, Waterford, N. Y. | '73 |
| **Pluemer, A., | Fourth and Race Streets, Cincinnati, Ohio. | '81 |
| *Plumb, Robert E., | 1 Newberry & McMillan Building, Detroit, Mich. | '84 |
| *Plummer, John W., Jr., | Granite, Philipsburg P. O., Montana. | '80 |
| *Pollard, John H., | Ashland, Pa. | '84 |
| *Pomeroy, Richard A., | Lock Box 9, Murray, Idaho. | '82 |
| *Pomeroy, S. Harris, | Pittsfield, Mass. | '84 |
| *Poole, Henry S., | Stellarton, Nova Scotia. | '85 |
| *Porter, George A., | Syracuse, N. Y. | '84 |
| †Porter, H. H., Jr, | 168 W. Forty-seventh Street, New York City. | '86 |
| *Porter, H. K., | Pittsburgh, Pa. | '86 |
| *Porter, J. A., | Durango, Colorado. | '74 |
| *Porter, J. C., | Spang Steel and Iron Co., Pittsburgh, Pa. | '82 |
| *Porter, John B., | 17 W. Third Street, Cincinnati, Ohio. | '83 |
| *Pott, John N., | 883 Hamilton Street, Allentown, Pa. | '76 |
| *Potter, Edward C., | North Chicago Rolling Mill Co., Chicago, Ill. | '79 |
| *Potter, O. W., | 17 Metropolitan Block, Chicago, Ill. | '75 |
| *Potter, Prof. William B., | Washington University, St. Louis, Mo. | '71 |
| *Potts, F. L., | 3802 Locust Street, Philadelphia, Pa. | '82 |
| *Potts, J. Thorpe, | 119 S. Fourth Street, Philadelphia. | '75 |
| *Powel, De Veaux, | R. H. Powel's Sons & Co., Philadelphia. | '84 |
| *Powell, J. W., | P. O. Box 585, Washington, D. C. | '76 |
| *Powell, W. H., | Belleville, Ill. | '85 |
| *Pratt, Nat. W., | 30 Cortlandt Street, New York City. | '86 |
| *Presbrey, Oliver S., | Port Henry, Essex Co., N. Y. | '78 |
| *Prevost, S. M., | 233 S. Fourth Street, Philadelphia, Pa. | '81 |

| | | |
|---|---|---|
| *Price, E. A., | Casa Grande, Arizona. | '85 |
| *Price, John B., | Mauch Chunk, Pa. | '86 |
| *Price, Saml. B., Jr., | West Leisenring, Pa. | '86 |
| *Price, Thomas, | 524 Sacramento Street, San Francisco, Cal. | '85 |
| *Prime, Frederick, Jr., | 222 S. Third Street, Philadelphia. | '71 |
| *Prince, F., | Tower, St. Louis Co., Minn. | '81 |
| *Provis, John, | Camborne, Cornwall, England. | '78 |
| *Provis, Thomas B., | 19 and 20 Finsbury Chambers, Finsbury Pavement, London, N., Eng. | '83 |
| *Pugh, Charles E., | 233 S. Fourth Street, Philadelphia. | '81 |
| **Pullman, J. Wesley, | 240 S. Third Street, Philadelphia. | '81 |
| *Pumpelly, Prof. Raphael, | U. S. Geological Survey, Newport, R. I. | '71 |
| *Rader, Charles I., | Paxton Furnace, Harrisburg, Pa. | '75 |
| †Radford, W. H., | North Bloomfield, Nevada Co., Cal. | '76 |
| *Raht, A., | Wickes, Montana. | '86 |
| *Rand, Addison C., | 23 Park Place, New York City. | '76 |
| *Rand, Jasper R., | 23 Park Place, New York City. | '82 |
| †Rand, Theodore D., | 17 S. Third Street, Philadelphia. | '73 |
| *Randol, James B., | New Almaden, Santa Clara Co., Cal. | '79 |
| *Randolph, John C. F., | 35 Broadway, New York City. | '75 |
| *Randolph, Marion, | 133 Jay Street, Albany, N. Y. | '83 |
| *Rathbone, Edgar P., | 2 Great George St., Westminster, London, S. W., Eng. | '82 |
| *Rattle, W. J., | 58 Grand Arcade Building, Cleveland, Ohio. | '84 |
| *Raymond, R. M., | Haile Gold Mine, S. C. | '85 |
| *Raymond, R. W., | P. O. Box 223, New York City. | '71 |
| †Rea, Wm. H., | Robinson Rea Manufacturing Co., Pittsburgh, Pa. | '86 |
| *Read, Chas. H., | Box 975, Pittsburgh, Pa. | '86 |
| *Reed, S. Albert., | 6 E. Fifty-third Street, New York City. | '75 |
| *Reese, Jacob, | 108 Diamond Street, Pittsburgh, Pa. | '72 |
| *Reid, R. B., | Dunbar, Pa. | '82 |
| †Reinecke, Conrad, | Belleville, Ill. | '86 |
| *Reinhardt, H. O., | Santa Eulalia Silver Mine, Chihuahua, Mexico. | '83 |
| *Reuleaux, J., | Care F. Vander Buecken, 2043 Chestnut St., Philadelphia. | '85 |
| *Revere, Joseph W., | Gowrie Mines, Cow Bay, C. B., Nova Scotia. | '81 |
| *Rhodes, Armitage, | 184 Mansfield Street, Montreal, Canada. | '82 |
| *Rhodes, F. B. F., | P. O. Box 726, Quebec, Canada. | '76 |
| †Rich, Jacob M., | 50 W. Thirty-eighth Street, New York City. | '83 |
| *Richards, Edgar, | U. S. Department of Agriculture, Washington, D. C. | '79 |
| *Richards, Ellen H., | Institute of Technology, Boston, Mass. | '79 |
| *Richards, E. Windsor, | Middlesbrough, England. | '81 |
| *Richards, George, | Dover, N. J. | '75 |
| *Richards, Henry, | Dover, N. J. | '77 |
| **Richards, John Thompson, | Scorries, Cornwall, England. | '84 |
| *Richards, Prof. R. H., | Institute of Technology, Boston, Mass. | '73 |
| *Richards, William L., | Blossburg, Tioga Co., Pa. | '80 |
| *Rickard, Alfred, | Idaho Springs, Colorado. | '84 |
| *Rickard, Reuben, | Berkeley, Cal. | '84 |
| *Rickard, R. D., | 15 Broad Street, New York City. | '80 |
| *Rickard, Thomas, | 58 Lombard Street, London, E. C. Eng. | '85 |

†Ricketson, J. H., . . . . 10 Wood Street, Pittsburgh, Pa. '72
*Ricketts, Dr. P. De P., . . . School of Mines, New York City. '73
*Rider, William E., . . . . P. O. Box 2180, New York City. '82
*Ridgely, Charles, . . . . Springfield Iron Co., Springfield, Ill. '75
*Ridgely, William B., . . . Springfield Iron Co., Springfield, Ill. '80
*Riggs, George W., . . 115 W. Forty-seventh Street, New York City. '74
*Riley, James, . . . . . 150 Hope Street, Glasgow, Scotland. '82
*Riley, Lewis A., . . . . . Ashland, Schuylkill Co., Pa. '76
*Riley, S. M., . . . . . Ashland, Schuylkill Co., Pa. '82
*Rinard, John, . . . . . Braddock, Allegheny Co., Pa. '79
*Ringeling, Frank, . . . . . Butte City, Montana. '86
*Riordan, D. M., . . . . . Flagstaff, Arizona. '82
*Riotte, Eugene N., . . . 104 Washington Street, New York City. '83
*Risque, J. B., . . . . . Albuquerque, N. M. '83
†Ritterskamp, Louis H., . . . . 206 Vine Street, St. Louis, Mo. '81
*Robbins, G. Collier, . . . . Amherstburg, Ontario, Canada. '79
*Roberts, Percival, . . . . 261 S. Fourth Street, Philadelphia. '81
*Roberts, Percival, Jr., . . . 261 S. Fourth Street, Philadelphia. '77
*Robertson, David, . . . . . Dagus Mines, Pa. '85
*Robertson, Kenneth, . . . Seacaucus Iron Co., Seacaucus, N. J. '82
*Robertson, W. F., . . . . . Springhill, Nova Scotia. '81
*Robeson, J. S., . . . . . Braddock, Pa. '85
*Robinson, Arthur, . . . . . Coalburgh, W. Va. '86
*Robinson, Chas. S., . . . . . Shurt's Hotel, Joliet, Ill. '85
*Robinson, Davis S., . . . . . Saltsburg, Pa. '85
*Robinson, Geo. H., . . . . . Helena, Montana. '86
*Robinson, Neil, . . . . . Coalburgh, W. Virginia. '85
*Robinson, Saml. J., . . . . . Saltsburg, Pa. '86
*Robinson, Theodore W., . . . . Shurt's Hotel, Joliet, Ill. '84
*Roby, Luther A., . . . Otis Iron and Steel Co., Cleveland, Ohio. '79
*Roepper, Charles W., . . . . . Alliance, Ohio. '73
*Rogers, A. N., . . . . . Central City, Colorado. '82
*Rogers, C. L., . . . . . 2601 Archer Avenue, Chicago, Ill. '80
*Rogers, E. M., . . . . . Central City, Colorado. '82
*Rolker, Charles M., . . . . 18 Broadway, New York City. '74
*Ronaldson, Charles E., . . . 1001 Chestnut Street, Philadelphia. '84
*Roney, C. Henry, . . . . 110 S. Fourth Street, Philadelphia. '77
*Roney, C. J., . . . . . Box 445, S. Bethlehem, Pa. '82
*Roney, W. R., . . . . . Las Cruces, N. M. '82
†Rose, William J., . . . . 12 N. Third Street, Harrisburg, Pa. '81
*Rose, William W., Jr., . . . P. O. Box 2391, Denver, Colorado. '82
*Rosecrans, Gen. W. S., . . . . . San Francisco, Cal. '76
*Ross, Frank A., . . . . . Hecla, Montana. '85
*Rothwell, R. P., . . . . . P. O. Box 1833, New York City. '71
*Rueger, C. C., . . . . . Anaconda, Montana. '85
*Russell, Edward H., . . . . . Park City, Utah. '84
†Russell, S. Bent, . . . . . 711 Pine Street, St. Louis, Mo. '81
*Russell, W. S., . . . . Foot of Walker Street, Detroit, Mich. '86
*Rutherford, J. George, . . Albion Mine, Stellarton, Nova Scotia. '83
*Ruttmann, Ferd. S., . . . . . 51 Broadway, New York City. '81

*Saint, William, . . . . . Porth, South Wales. '84
*Salom, Pedro G., . . . . 208 S. Fourth Street, Philadelphia. '80
**Sandberg, C. P., 19 Great George St., Westminster, London, S. W., England. '81
*Sanders, John D., . . . . . Mine La Motte, Missouri. '79
†Sanders, W. E., . . . . . Butte City, Mont. '85
*Sands, Ferdinand, . . . . . Steinway, L. I., N. Y. '81
*Sargent, George W., . . Lake George, York Co., N. B., Canada. '82
*Saunders, William L., . . . . 10 Park Place, New York City. '83
†Sawyer, Henry H., . . . . . Easthampton, Mass. '82
†Scaife, Chas. C., . . . . 119 First Avenue, Pittsburgh, Pa. '86
**Scaife, Oliver P., . . . . 119 First Avenue, Pittsburgh, Pa. '78
*Scaife, William Lucien, . . . . . Pittsburgh, Pa. '79
*Schaeffer, Prof. Charles A., . Cornell University, Ithaca, N. Y. '74
*Schamberg, Meyer, Care W. G. Wilson, 212 N. Front Street, Philadelphia. '83
*Scharar, C. H., . . . . . 2073 N. Main Ave., Scranton, Pa. '82
*Schaufuss, Eric C., . . . . . Wilkesbarre, Pa. '83
*Schellenberg, F. Z., . . . . Irwin's, Westmoreland Co., Pa. '79
*Schmitz, E. J., . . . 202 E. Seventy-sixth Street, New York City. '83
*Schneider, Albert F., . . . . . Argentine, Kansas. '74
†Schoonmaker, S. L., . . . . 120 Water Street, Pittsburgh, Pa. '86
*Schulze-Berge, H., . . . . . P. O. Box 2178, New York City. '81
†Schwartz, J. E., . . . . . P. O. Box, 1062, Pittsburgh, Pa. '76
*Schwarz, T. E., . . P. O. Box 137, Silverton, San Juan Co., Colorado. '76
*Scott, C. A., . . . . . Halifax, Nova Scotia. '82
*Scovel, Minor, . . . . . 55 Lewis Block, Pittsburgh, Pa. '85
*Scranton, W. H., . . . . . Fall River, Mass. '71
*Scranton, W. W., . . . . . Scranton, Pa. '75
*Seaman, H. J., . . . . . Catasauqua, Pa. '82
†Searle, J. M., . . . . . Stanhope, N. J. '84
*Sears, Edward H., . . . . . Collinsville, Conn. '81
**Seligman, A. J., . . . . . Helena, Montana. '82
*Sellers, Morris, . . . . . 6 Ashland Block, Chicago, Ill. '84
*Sellers, William, . . . . 1600 Hamilton Street, Philadelphia. '75
*Setz, Gustav, St. Joseph Lead Mines, Bonne Terre, St. François Co., Mo. '77
*Sharples, S. P., . . . . . 13 Broad Street, Boston, Mass. '78
*Shaw, H. C., . . . . . Care Dr. Shaw, Pittsburgh, Pa. '81
*Shaw, R. C., . . . . . Tombstone, Arizona. '84
*Sheafer, A. W., . . . . . Pottsville, Pa. '80
*Sheafer, P. W., . . . . . Pottsville, Pa. '74
*Sheafer, S. Taylor, . . . . . Fairmount City, Pa. '85
*Sheafer, W. Lesley, . . . . . Pottsville, Pa. '81
*Shed, Nathaniel W., . . . . . Nashua, N. H. '82
*Sherman, George R., . . . . Port Henry, Essex Co., N. Y. '78
*Sherrerd, Alexander H., Lackawanna Iron and Coal Co., Scranton, Pa. '75
*Sherrerd, John M., Albany and Rensselaer Iron & Steel Co., Troy, N. Y. '80
*Shimer, Porter W., . . . . . Easton, Pa. '79
*Shinn, William P., . . . . 22 Cortlandt Street, New York City. '75
*Shockley, W. H., . . . . Candelaria, Esmeralda Co., Nevada. '83
†Shoemaker, A. T., . . . . . 11 Pine Street, New York City. '83
*Shoenbar, John, . . . . West Sullivan, Hancock Co., Maine. '77

*Shook, A. M., . . . . . Tracy City, Tenn. '85
*Shumway, W. Adams, . . . Geol. Survey, Washington, D. C. '81
*Silliman, Prof. J. M., . . . . Lafayette College, Easton, Pa. '71
*Simpson, C. D., . . . . . Scranton, Pa. '85
*Sims, Alfrew W., . . . . . Orbisonia, Pa. '85
*Sims, H. N., . . . . . Huntingdon, Huntingdon Co., Pa. '83
*Singer, George, . . . . . 111 Fourth Ave., Pittsburgh, Pa. '85
*Singer, William H., . . . . 83 Water Street, Pittsburgh, Pa. '73
*Singer, R. R., . . . . . 83 Water Street, Pittsburgh, Pa. '79
*Slack, Chas. G., . . . . . Marietta, Ohio. '86
*Slade, F. J., . . . New Jersey Steel and Iron Co., Trenton, N. J. '74
*Sloss, Fred., . . . . . Birmingham, Ala. '86
*Sluder, Edwin E., . . . . . Cerillos, N. Mexico. '83
**Small, Geo. W., . . . . . Oconomowoc, Wis. '85
*Smalley, W. A., . . . . . Georgetown, New Mexico. '80
*Smith, Frank C., . . . 89 Wisconsin Street, Milwaukee, Wis. '84
*Smith, Geo. A., . North Chicago Rolling Mill Co., South Chicago, Ill. '85
*Smith, Hamilton, Jr., 5 Union Court, Old Broad Street, London, Eng. '77
*Smith, H. S., . . . . . Joliet, Ill. '75
*Smith, J. William, . . . . Solvay Process Co., Syracuse, N. Y. '81
*Smith, Michael, . North Chicago Rolling Mill Co., S. Chicago, Ill. '84
*Smith, Oberlin, . . . . . Bridgeton, N. J. '84
†Smith, Pemberton, . . . . . 30 Second Street, Troy, N. Y. '85
*Smith, T. Guilford, . . . . . P. O. Box 251, Buffalo, N. Y. '71
*Smith, William Allen, . . . 16 Exchange Place, New York City. '73
*Smith, Gen. Wm. Sooy, . . . 2 Nassau Street, New York City. '76
*Smock, Prof. John C., . . . N. Y. State Museum, Albany, N. Y. '73
*Smyth, C. H., . . . . Franklin Iron Works, Oneida Co., N. Y. '82
*Snyder, J. F., . . . . . 1015 Vine Street, Scranton, Pa. '76
*Soule, R. H., . . . . N. Y., L. E. & W. R. R., Buffalo, N. Y. '81
*Speer, John Z., . . . . . Shoenberger & Co., Pittsburgh, Pa. '79
†Spencer, William, . . . . Buck Mountain, Carbon Co., Pa. '72
†Sperr, Fred W., . . . . . Jefferson, Ohio. '82
*Spies, Albert, . . . . 901 Summit Avenue, Jersey City, N. J. '81
*Spilsbury, E. G., . . . . . Haile Mine, S. C. '73
*Springer, Dr. Alfred, . . . P. O. Box 579, Cincinnati, Ohio. '84
*Springer, Chas. L., . . . . . Oliphant Furnace, Pa. '86
**Squire, Joseph, . . . . . Helena, Shelby Co., Alabama. '71
*Stafford, C. Edward, . . Care Shoenberger & Co., Pittsburgh, Pa. '74
†Stanton, John, . . . . . 76 Wall Street, New York City. '77
†Staunton, Gray, . . . 464 Farmington Avenue, Hartford, Conn. '85
*Staunton, William F., Jr., . . . . . Tombstone, Arizona. '83
*Stearns, I. A., . . . . . Wilkes-Barre, Pa. '71
*Stetefeldt, C. A., . . . . . 18 Broadway, New York City. '81
†Stetson, Edw. I. E., . . . . . Box 36, South Bethlehem, Pa. '85
†Stetson, George W., . . . 69 Wall Street, New York City. '83
*Stevenson, John, Jr., . . . . . New Castle, Pa. '76
*Steyern, Baltzar von, . . . . . Falun, Sweden. '85
*Sticht, Ernest . . . . . 754 Flushing Avenue, Brooklyn. '85
*Sticht, Robert, . . . . P. O. Box 68, South Pueblo, Colorado. '85

*Stillman, Prof. T. B., . . . Stevens' Institute, Hoboken, N. J. '85
*Stirling, W. R., . . . . . Joliet Steel Co., Chicago, Ill. '84
*Stockett, Lewis, . . . . . Staunton, Ill. '81
*Stockwell, Nathaniel S., . U. S. Patent Office, Washington, D. C. '85
*Stoiber, Edward G., . . . . . Silverton, Colorado. '77
*Stone, Gen. Charles P., . . . . 1 Broadway, New York City. '84
†Stone, George C., . . . N. J. Zinc and Iron Co., Newark, N. J. '80
*Storrs, A. H., . . . . . Shamokin, Pa. '84
*Strauch, John H., . . . . . Pottsville, Pa. '83
*Strausz, Alexander, . . . Independence, Preston Co., W. Va. '81
*Strickland, Herbert, . . . P. O. Box 88, Leadville, Colorado. '84
*Strieby, Prof. William, . Colorado College, Colorado Springs, Colorado. '77
*Strobel, V. O., . . . . . 226 Walnut Street, Philadelphia. '84
*Strode, Prof. H. A., . . . . . Amherst, Va. '81
*Stutz, Sebastian, . . . . . P. O. Box 112, Pittsburgh, Pa. '79
*Suppes, Max M., . . . . . 188 First Street, Troy, N. Y. '83
†Swain, Edw. A., . . . . . 34 Nassau Street, New York City. '86
*Swett, George W., . . . . . Troy, N. Y. '83
*Swindell, William, . . . . 48 Esplanade Street, Allegheny, Pa. '79
*Symington, W. N., . . . . . P. O Box 2011, New York City. '73
*Symons, W. R., . . . . . Pottsville, Pa. '71

*Taylor, Fred. W., . . . P. O. Box 10, Hillsborough, New Mex. '81
†Taylor, P. A., . . . . . Pottsville, Pa. '80
**Taylor, Percyvale, . . . 6 Rue de Caumartin, Paris, France. '81
*Taylor, Selwyn, . . . . . 161 Fifth Avenue, Pittsburgh, Pa. '86
*Taylor, W. J., . . . . . Chester, Morris Co., N. J. '75
*Terhune, R. H., . . . . . Salt Lake City, Utah. '86
*Thacher, Arthur, . . . 61 Broadway, Room 25, New York City. '75
*Thackray, George E., . . . . P. O. Box 789, New York City. '80
*Thaw, William, Jr., . . . . . Pittsburgh, Pa. '82
*Thies, A., . . . . . Concord, N. C. '78
*Thomas, Alexander, . . . . Bolton Steel Co., Canton, Ohio. '81
*Thomas, D. H., . . . . . Hokendauqua, Pa. '80
*Thomas, Edwin, . . . . . Hokendauqua, Pa. '79
*Thomas, Fred. F., . . . . . Kennedy Mine, Jackson, Cal. '84
*Thomas, John, . . . . . Hokendauqua, Pa. '71
*Thomas, Samuel, . . . . . Catasauqua, Pa. '71
*Thomé, Samuel W., . . . . 397 Fulton Street, Brooklyn, N. Y. '81
*Thomlinson, William, . . . . West Hartlepool, England. '81
*Thompson, E. Ray, . . . . . Troy, N. Y. '79
†Thompson, George S., . . . . . Troy, N. Y. '83
*Thompson. Heber S., . . . . . Pottsville, Pa. '76
*Thompson, Robert M., . . . 37 Wall Street, New York City. '81
*Thomson, John L., P. O. Box 44, New Brighton, Staten Island, N. Y. '81
*Thropp, Jos. E., . . . . . Edge Hill Furnace, Pa. '85
*Thurston, Prof. R. H., . . . Cornell University, Ithaca, N. Y. '75
*Tierney, John J., . . . . . Bramwell, Mercer Co., W. Va. '83
*Tilemann, J. N., . . . . . Sandy, Utah Ter. '81
*Todd, James, . . . . . Box 121, Leechburg, Pa. '83

| | | |
|---|---|---|
| *Tonnelé, Theodore, | McKeesport, Pa. | '84 |
| *Torrance, H. C., | Care Port Henry Steel and Iron Co., Lim., Port Henry, N. Y. | '81 |
| *Torrance, J. Fraser, | 16 St. John Street, Montreal, Canada. | '76 |
| *Torrey, Dolphus, | 216 Adams Street, Brooklyn, N. Y. | '78 |
| **Torrey, Herbert G., | U. S. Assay Office, New York City. | '81 |
| *Toucey, Donald B., | 43 W. Fifty-third Street, New York City. | '81 |
| *Tower, A., | Poughkeepsie, N. Y. | '78 |
| *Towne, Linwood O., | Rico, Dolores Co., Colorado. | '81 |
| *Townsend, David, | 1723 Wallace Street, Philadelphia. | '80 |
| *Townsend, Henry T., | 218 S. Fourth Street, Philadelphia. | '79 |
| *Treat, F. H., | P. O. Box 1168, Joliet, Ill. | '86 |
| *Trent, L. C., | 7 West Second South Street, Salt Lake City, Utah. | '78 |
| *Trippel, Alexander, | Old Dominion Copper Mining Co., Globe, Arizona. | '83 |
| *Trowbridge, Prof. William P., | School of Mines, New York City. | '77 |
| *Tyler, Alfred L., | Woodstock Iron Co., Anniston, Ala. | '75 |
| *Tyson, J. W., | Baltimore, Md. | '86 |
| *Uehling, Edw. A., | Sharpsburg, Pa. | '86 |
| *Valentine, M. D., | Woodbridge, N. J. | '76 |
| *Van Arsdale, W. H., | Aurora, Ill. | '72 |
| *Van Blarcom, E. C., | P. O. Box 2085, San Francisco, Cal. | '79 |
| *Van Diest, P. H., | 379 Twenty-second Street, Denver, Colorado. | '82 |
| †Van Frank, Phil., | Hopewell Furnace, Mo. | '86 |
| *Vandling, A. H., | Scranton, Pa. | '82 |
| *Van Hise, C. R., | Madison, Wis. | '85 |
| *Van Slooten, Wm., | 95 Milk Street, Boston, Mass. | '84 |
| *Van Tassel, Howard A., | Atlantic Mine, Houghton Co., Mich. | '81 |
| *Van Voorhis, W. W., | Manhattanville, New York City. | '79 |
| *Veeder, Herman, | 210 Lake Street, Chicago, Ill. | '80 |
| *Vezin, Henry A., | P. O. Box 144, Leadville, Colorado. | '74 |
| †Viennot, J., | 150 South Fourth Street, Philadelphia, Pa. | '86 |
| *Vivian, George G., | Freeland, Clear Creek Co., Colorado. | '82 |
| *Vulté, Hermann T., | School of Mines, New York City. | '81 |
| *Wagner, E. C., | Girardville, Pa. | '85 |
| *Wait, Prof. Charles E., | Rolla, Phelps Co., Missouri. | '79 |
| *Waite, George R., | 220 S. Broad Street, Philadelphia. | '76 |
| *Walter, Arthur L., | Globe, Arizona. | '85 |
| *Walker, J. C., | 238 Bissell Street, Chicago, Ill. | '83 |
| †Walker, John A., | P. O. Box 21, Jersey City, N. J. | '78 |
| †Walker, Joseph R., | Salt Lake City, Utah. | '85 |
| *Walker, T. B., | Ashland, Ky. | '84 |
| *Walker, W. J. B., | Mannsfield Valley, Pa. | '86 |
| *Walker, W. R., | Union Steel Co., Chicago, Ill. | '81 |
| **Waller, Dr. Elwyn, | School of Mines, New York City. | '83 |
| *Wallis, Philip, | Box 1973, Aurora, Ill. | '84 |
| *Walsh, Edward, Jr., | Main and Angelica Streets, St. Louis, Mo. | '74 |
| *Walter, T. Frank, | Mauch Chunk, Pa. | '84 |

*Ward, Willard P., . . . 80 Madison Avenue, New York City. '71
*Warren, George Henry, Jr., . . 520 Fifth Avenue, New York City. '81
*Warren, Walter P., . . . . . Troy, N. Y. '83
**Wartenweiler, Alfred, . . . . . Butte City, Montana. '75
*Waterman, H. L., Care of C. H. Odell, 15 Broad Street, New York City. '81
*Waters, J. H. E., . . . . . Silverton, Colorado. '82
*Watts, David, . . . . . 223 Market Street, Harrisburg, Pa. '81
*Weaver, V. W., . . . . . Macungie, Lehigh Co., Pa. '82
*Webb, H. H., . . . . 405 Front Street, San Francisco, Cal. '85
*Webb, H. Walter, . . . . . 37 Wall Street, New York City. '82
*Weeks, Joseph D., . . . . . P. O. Box 1547, Pittsburgh, Pa. '75
*Weidman, Barge C., . . . . P. O. Box 175, S. Bethlehem, Pa. '84
*Weimer, Asa A., . . . . . Lebanon, Pa. '85
*Weimer John A., . . . . . Lebanon, Pa. '85
*Weir, Charles G., . . . . . Cheyenne, Wyoming. '82
*Weiser, Frank P., . . . . . Ashland, Pa. '84
*Weitzell, Richard S., . . . . . Logan, Ohio. '85
**Wellman, S. T., . . . Otis Iron and Steel Co., Cleveland, Ohio. '75
*Wells, Bard, . . . . . Pottsville, Pa. '80
†Wells, Calvin, . . . . . A. French & Co., Pittsburgh, Pa. '73
*Wells, H. L., . . . Sheffield Scientific School, New Haven, Conn. '81
*Wendt, Arthur F., . . . . . Box 1600, New York City. '74
*Westbrook, Charles R., . . Ogdensburgh, St. Lawrence Co., N. Y. '80
*Westbrook, C. S., . . . Spragueville, St. Lawrence Co., N. Y. '83
*Westesson, Josef P. L., . . . 208 S. Fourth Street, Philadelphia. '84
*Westinghouse, Geo., Jr., . . . . . Pittsburgh, Pa. '86
*Weston, Francis E., . . . . . Upland, Pa. '85
*Wheeler, H. A., . . . Washington University, St. Louis, Mo. '81
*Wheeler, Moses D., . . P. O. Box 539, Stapleton, Staten Island, N. Y. '75
*Wheeler, William D., . . U. S. Assay Office, Helena, Montana. '81
*Wheelock, Jerome, . . . . . Worcester, Mass. '82
*Whinery, S., . . . . . Somerset, Ky. '80
*Whitaker, Thomas D., . . Cedar Grove, Frankford, Philadelphia. '84
*Whitcomb, George D., . . Dearborn & Monroe Streets, Chicago, Ill. '83
*White, Jas. B., . . . . Bissell Block, Room 19, Pittsburgh, Pa. '86
*White, William, Jr., . . . . P. O. Box 36, Pittsburgh, Pa. '79
*Whiting, Henry A., . . Care S. A. Blatchford, 16 Exchange Place, N. Y. '85
*Whiting, S. B., . . . . . Pottsville, Pa. '71
†Whitman, James N., . . . . . Syracuse, N. Y. '83
*Whitney, Eli, Jr., . . Whitneyville Armory, New Haven, Conn. '75
*Wickes, George T., . . . . . Bozeman, Montana. '76
*Wiestling, George B., . . . . Mont Alto, Franklin Co., Pa. '77
*Wight, Sidney B., . . . . . Newberry, Mich. '80
*Wilcox, John F., . . . Care J. P. Witherow, Pittsburgh, Pa. '86
*Wilcox, Stephen, . . . . 30 Cortlandt Street, New York City. '85
*Wiles, Edwin L., . . . . Springfield Iron Co., Springfield, Ill. '82
*Wiley, William H., . . . . 15 Astor Place, New York City. '81
*Wilhelm, A., . . . . . P. O. Box 178, Harrisburg, Pa. '77
*Wilkes, John, . . . . . Charlotte, N. C. '83
*Williams, Albert, Jr., . . . . Box 591, Washington, D. C. '82

*Williams, Ben., . . . . . Bisbee, Arizona. '82
*Williams, David, . . . . . 66 Duane Street, New York City. '80
*Williams, Prof. Edward H., Jr., . . P. O. Box 463, Bethlehem, Pa. '76
*Williams, Frederick H., . . . . . Box 502, Orange, N. J. '80
**Williams, Gardner F., . . 2131 Telegraph Avenue, Oakland, Cal. '86
*Williams, Henry, . . . . . Butte City, Montana. '75
*Williams, Henry S., . . . . Cornell University, Ithaca, N. Y. '86
*Williams, Prof. J. F., . . . . . Troy, N. Y. '83
*Williams, John J., . . . . . 25 Davis Street, San Francisco, Cal. '83
*Williams, John T., Room 13, Cotton Exchange Building, New York City. '74
*Williams, Lewis, . . . . . Bisbee, Arizona. '83
*Williams, Samuel T., . Care of Henry Disston & Sons, Philadelphia. '79
*Wilson, Eugene B., . . . . Cross Creek Collieries, Drifton, Pa. '83
*Wilson, John A., . . . . . 435 Chestnut Street, Philadelphia. '76
*Wilson, J. Chester, . . . . . 419 Walnut Street, Philadelphia. '84
*Wilson, Joseph M., North Chicago Rolling Mill Co., South Chicago, Ill. '82
*Wilson, N. R., . . . . . P. O. Box 517, Leadville, Colorado. '81
*Wilson, William A., . . . . . Park City, Utah. '83
*Wiltsie, E A., . . . Edgar Thompson Steel Works, Braddock, Pa. '86
*Winslow, Arthur, . . . . . P. O. Box 274, Raleigh, N. C. '81
†Wishon, Walter W., . . . . . Colorado Springs, Colorado. '82
*Wister, Jones, . . . . . 230 S. Fourth Street, Philadelphia. '79
*Witherbee, Frank S., . . . . . Port Henry, Essex Co., N. Y. '76
**Witherbee, T. F., . . . . . Port Henry, Essex Co., N. Y. '71
*Witherbee, W. C., . . . . . Port Henry, Essex Co., N. Y. '80
*Witherow, J. P., Lewis Block, 6th Ave. and Smithfield St., Pittsburgh, Pa. '76
*Witherspoon, James, . . . . . Laredo, Texas. '81
†Wittmack, Charles A., . . . P. O. Box 1032, New York City. '82
*Wittman, N. B., . . . . . Birdsboro, Pa. '84
†Wolcott, Henry R., . . . . P. O. Box 2915, Denver, Colorado. '82
*Wolf, Theodore G., . . . . . Scranton, Pa. '79
*Wolfe, Albert H., . . . La Salle and Adams Streets, Chicago, Ill. '82
**Wolff, Dr. Fr. M., . . 12 Hohenzollernstrasse, Berlin, W., Prussia. '82
*Woliston, R. T., . . . . . Isle, Custer Co., Colorado. '85
*Wood, A. B., . . . . . Ann Arbor, Mich. '82
*Wood, Frederick W., . . . . . Steelton, Dauphin Co., Pa. '79
*Wood, Thomas D., . . . . . McKeesport, Pa. '79
*Wood, Walter, . . . . . 400 Chestnut Street, Philadelphia. '85
†Wood, W. Dewees, . . . . 111 Water Street, Pittsburgh, Pa. '83
*Woodbury, L. S., . . . . . Calumet, Mich. '80
*Woodward, E. H., . . . . . 54 Cliff Street, New York City. '81
*Woodward, W. H., . . . . . Wheeling, Ala. '84
*Worthington, Chas. C., . . . . . 145 Broadway, New York. '85
*Wright, Charles E., . . . . . Marquette, Mich. '80
*Wright, James N., . . . . . Calumet, Mich. '79
**Wright, Whitaker, . . 18 Merchants' Exchange, Philadelphia. '81
*Wurts, Charles P., . . . . . New Haven, Conn. '81
**Würgler, A., . . . . . 7 Rue Viète, Paris, France. '85

*Yardley, Thomas W., . . . . . Troy, N. Y. '83

*Yeatman, Pope, . . . . . Zacatecas, Mexico. '83
**Young, James B., . . . . Phœnix Roll Works, Pittsburgh, Pa. '79

*Zacharias, H. C., . . . . . Shamokin, Pa. '84
†Zuckoski, Edmund L., . . . . 1829 Kennett Place, St. Louis, Mo. '84

Honorary Members, 7; Members, 1292; Associates, 157; Foreign Members, 48.

# Deceased.

ATKINS, C. M., JR., . . . . . 1885
BLOSSOM, T. M., . . . . . 1876
BRIGGS, ROBERT, . . . . . 1882
BRINSMADE, J. B., . . . . . 1884
BROWN, A. J., . . . . . 1875
BROWNING, F. D., . . . . . 1885
CALDWELL, W. B., JR., . . . . . 1880
CAMERON, JAMES R., . . . . . 1881
CHISHOLM, HENRY, . . . . . 1881
CLARK, HENRY G., . . . . . 1881
CLARK, WILLIAM, . . . . . 1884
CLAYTON, W. S., . . . . . 1886
CLEMES, J. P., . . . . . 1876
CONVERSE, JAMES B., . . . . . 1883
CROCKER, WILLIAM B., . . . . . 1885
DADDOW, S. H., . . . . . 1875
D'ALIGNY, H. F. Q., . . . . . 1875
DAVIDSON, D. R., . . . . . 1884
DAVIES, EDW. S., . . . . . 1885
DE PEIGER, R. F. J., . . . . . 1883
DICKSON, THOMAS, . . . . . 1884
DRESSER, CHARLES A., . . . . . 1878
DWIGHT, W. S., . . . . . 1883
FERNEKES, ANTON, . . . . . 1884
FIRMSTONE, WILLIAM, . . . . . 1877
FISHER, HARVEY, . . . . . 1885
FULLER, JOHN T., . . . . . 1880
GOULD, ROBERT A., . . . . . 1878
GRIFFEN, JOHN, . . . . . 1884
GRUNER, L., . . . . . 1883
HALL, JAMES F., . . . . . 1884
HARRIS, STEPHEN, . . . . . 1874
HEALY, MORRIS, . . . . . 1881
HEINRICH, OSWALD, . . . . . 1886
HOLLEY, A. L., . . . . . 1882
HORTON, N. W., . . . . . 1886
HUNT, THOMAS, . . . . . 1872
HUSSEY, C. C., . . . . . 1884
HYNDMAN, E. K., . . . . . 1884
INGERSOLL, S. WARREN, . . . . . 1884
JENNEY, F. B., . . . . . 1876
JERNEGAN, J. L., . . . . . 1881
KERR, PROF. W. C., . . . . . 1885
LEE, WASHINGTON, . . . . . 1872
LEISENRING, JOHN, . . . . . 1874
LIEBENAU, CHARLES VON, . . . . . 1875
LORD, JOHN C., . . . . . 1872
LORENZ, W., . . . . . 1884

| | |
|---|---|
| Lorenz, W., Jr., | 1881 |
| Lowe, Francis A., | 1883 |
| McIntire, Henry M., | 1880 |
| McKee, David, | 1884 |
| Mackintosh, W. S., | 1884 |
| MacMartin, Archibald, | 1881 |
| Manthey, William, | 1883 |
| Mickley, J. W., | 1880 |
| Moore, Charles W., | 1877 |
| Newton, Henry, | 1877 |
| Newton, Isaac, | 1884 |
| Painter, Howard, | 1876 |
| Park, James, Jr., | 1883 |
| Phelps, Walter, | 1878 |
| Phillips, P. E., | 1884 |
| Pierson, O. H., | 1882 |
| Platt, W. G., | 1885 |
| Pleasants, Henry, | 1880 |
| Priest, J. R., | 1880 |
| Richter, C. E., | 1877 |
| Rickard, R. H., | 1885 |
| Robinson, Thomas W., | 1880 |
| Santa Maria, Raymundo de, | 1883 |
| Saylor, David O., | 1884 |
| Schirmer, J. F. L., | 1877 |
| Schuchard, Charles, | 1883 |
| Sickles, T. E., | 1885 |
| Siemens, C. William, | 1883 |
| Silliman, Prof. B., | 1885 |
| Steitz, Augustus, | 1876 |
| Sterling, Henry S., | 1882 |
| Stinson, John M., | 1884 |
| St. John, I. M., | 1880 |
| Stoelting, Hermann, | 1875 |
| Teft, Walter, | 1885 |
| Thomas, David, | 1882 |
| Thomas, Sidney G., | 1885 |
| Thompson, Prof. C. O., | 1885 |
| Thonard, Leon, | 1886 |
| Troilius, M., | 1886 |
| Walz, Isidor, | 1877 |
| Warner, L. E., | 1884 |
| Welch, Ashbel, | 1882 |
| Wendel, Dr. A., | 1881 |
| Wheatley, Charles M., | 1882 |
| Whilldin, W. I., | 1882 |
| Witherbee, J. G., | 1875 |
| Wood, Wm. J., | 1885 |
| Worthington, Henry R., | 1880 |
| Wright, Harrison, | 1885 |
| Wrigley, H. E., | 1882 |

# TABLE

## SHOWING THE OFFICERS OF THE INSTITUTE FROM ITS ORGANIZATION TO THE PRESENT TIME.

**The offices of President, Vice-President, Manager, Secretary and Treasurer are indicated by their initials.**

| | 1871 | 1872 | 1873 | 1874 | 1875 | 1876 | 1877 | 1878 | 1879 | 1880 | 1881 | 1882 | 1883 | 1884 | 1885 | 1886 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALEXANDER, JOHN S., | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... |
| ASHBURNER, C. A., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M |
| ASMUS, GEORGE, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... |
| BAYLES, JAMES C., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | P | P | ..... |
| BIRKINBINE, JOHN, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... |
| BLAIR, THOMAS S., | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| BLAKE, WILLIAM P., | V | V | V | V | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| BLANDY, JOHN F., | V | V | V | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| BROOKS, THOS. B., | ..... | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| BUCK, STUART M., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... |
| BURDEN, JAMES A., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... |
| BURNHAM, WILLIAM, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... |
| CHURCH, JOHN A., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... |
| COGSWELL, W. B., | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V |
| COOK, EDGAR S., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M |
| CORYELL, MARTIN, | S | S | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| COX, E. T., | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| COXE, ECKLEY B., | V | V | V | V | ..... | V | V | P | P | ..... | ..... | ..... | ..... | V | V | ..... |
| COXE, WM. E. C., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | M | M |
| DRINKER, HENRY S., | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| DROWN, THOMAS M., | ..... | M | S | S | S | S | S | S | S | S | S | S | S | ..... | ..... | ..... |
| DUDLEY, CHARLES B., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... |
| EGLESTON, THOMAS, | M | V | V | V | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | V | V | ..... |
| EILERS, ANTON, | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... |
| ELY, T. N., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... |
| EMMONS, S. F., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... |
| FIRMSTONE, FRANK, | ..... | ..... | M | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M |
| FRAZER, PERSIFOR, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... |
| FRAZIER, B. W., | ..... | ..... | ..... | M | M | M | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... |
| FRITZ, JOHN, | ..... | ..... | ..... | ..... | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| FULTON, JOHN, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V |
| GAUJOT, E., | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| HEINRICH, OSWALD J., | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| HEWITT, ABRAM S., | ..... | M | M | M | M | P | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| HOLLEY, A. L., | ..... | ..... | ..... | V | P | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| HOWE, H. M., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | M |
| HUNT, ROBERT W., | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | P | ..... | ..... | ..... |
| HUNT, T. STERRY, | ..... | ..... | M | M | M | ..... | P | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| JOHNSON, J. E., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M |
| KENT, JOSEPH C., | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| KERR, W. C., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... |
| KEYES, W. S., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... |
| KIMBALL, J. P., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... |
| LESLEY, J. P., | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| LEWIS, JAMES F., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | V |
| MACDONALD, CHARLES, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... |
| MAYNARD, GEORGE W., | M | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M |
| MCCREATH, ANDREW S. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... |
| MCNAIR, T. S., | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| METCALF, WILLIAM, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | P | ..... | ..... | ..... | ..... | ..... |
| MOFFAT, E. S., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... |
| MUNROE, H. S., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... |
| NEILSON, W. G., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M |
| NEWBERRY, J. S., | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| PEARCE, RICHARD, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V |
| PEARSE, JOHN B., | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| PECHIN, E. C., | ..... | M | V | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... |
| PETHERICK, THOMAS, | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| PETTEE, WM. H., | ..... | ..... | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... |
| POTTER, WILLIAM B., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... |
| POWELL, J. W., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... |
| PRIME, FRED., JR., | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| PUMPELLY, RAPHAEL, | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| RAND, THEODORE D., | ..... | ..... | T | T | T | T | T | T | T | T | T | T | T | T | T | T |
| RANDOLPH, J. C. F., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... |
| RAYMOND, R. W., | V | P | P | P | ..... | V | V | ..... | ..... | V | ..... | ..... | ..... | S | S | S |
| RICHARDS, ROBERT H., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | P |
| ROBERTS, PERCIVAL, JR. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... |
| ROTHWELL, RICHARD P. | M | V | V | ..... | V | V | ..... | ..... | ..... | ..... | ..... | P | ..... | ..... | ..... | ..... |
| SHINN, WILLIAM P., | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | P | ..... | ..... | ..... | ..... | ..... | ..... |
| SMOCK, JOHN C., | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| SPILSBURY, E. G., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | M | M |
| STETEFELDT, C. A., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V |
| SWOYER, J. H., | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| SYMONS, W. R., | V | V | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| THURSTON, ROBERT H., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| THOMAS, DAVID, | P | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| THOMAS, SAMUEL, | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... | ..... | ..... |
| THOMPSON, CHARLES O. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... | ..... | ..... |
| WEEKS, J. D., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V |
| WELLMAN, S. T., | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | V | V | ..... | ..... |
| WILLIAMS, T. M., | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| WILLIAMSON, J. PRYOR, | T | T | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| WITHERBEE, THOS. F., | ..... | ..... | ..... | ..... | ..... | M | M | M | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

## LIST OF THE MEETINGS OF THE INSTITUTE AND THEIR LOCALITIES FROM ITS ORGANIZATION TO FEBRUARY, 1885.

| Number. | Place. | Date. | Transactions. |
|---|---|---|---|
| I. | Wilkesbarre, Pa.,* | May, 1871, | i. 3 |
| II. | Bethlehem, Pa., | August, 1871, | i. 10 |
| III. | Troy, N. Y., | November, 1871, | i. 13 |
| IV. | Philadelphia, Pa., | February, 1872, | i. 17 |
| V. | New York, N. Y.,* | May, 1872, | i. 20 |
| VI. | Pittsburgh, Pa., | October, 1872, | i. 25 |
| VII. | Boston, Mass., | February, 1873, | i. 28 |
| VIII. | Philadelphia, Pa.,* | May, 1873, | ii. 3 |
| IX. | Easton, Pa., | October, 1873, | ii. 7 |
| X. | New York, N. Y., | February, 1874, | ii. 11 |
| XI. | St. Louis, Mo.,* | May, 1874, | iii. 3 |
| XII. | Hazleton, Pa., | October, 1874, | iii. 8 |
| XIII. | New Haven, Conn., | February, 1875, | iii. 15 |
| XIV. | Dover, N. J.,* | May, 1875, | iv. 3 |
| XV. | Cleveland, O., | October, 1875, | iv. 9 |
| XVI. | Washington, D. C., | February, 1876, | iv. 18 |
| XVII. | Philadelphia, Pa.,† | June, 1876, | v. 3 |
| XVIII. | Philadelphia, Pa., | October, 1876, | v. 19 |
| XIX. | New York, N. Y., | February, 1877, | v. 27 |
| XX. | Wilkesbarre, Pa.,* | May, 1877, | vi. 3 |
| XXI. | Amenia, N. Y., | October, 1877, | vi. 10 |
| XXII. | Philadelphia, Pa., | February, 1878, | vi. 18 |
| XXIII. | Chattanooga, Tenn.,* | May, 1878, | vii. 3 |
| XXIV. | Lake George, N. Y., | October, 1878, | vii. 103 |
| XXV. | Baltimore, Md.,* | February, 1879, | vii. 217 |
| XXVI. | Pittsburgh, Pa., | May, 1879, | viii. 3 |
| XXVII. | Montreal, Canada, | September, 1879, | viii. 121 |
| XXVIII. | New York, N. Y.,* | February, 1880, | viii. 275 |
| XXIX. | Lake Superior, Mich., | August, 1880, | ix. 1 |
| XXX. | Philadelphia, Pa.,* | February, 1881, | ix. 275 |
| XXXI. | Staunton, Va., | May, 1881, | x. 1 |
| XXXII. | Harrisburg, Pa., | October, 1881, | x. 119 |
| XXXIII. | Washington, D. C.,* | February, 1882, | x. 225 |
| XXXIV. | Denver, Col., | August, 1882, | xi. 1 |
| XXXV. | Boston, Mass.,* | February, 1883, | xi. 217 |
| XXXVI. | Roanoke, Va., | June, 1883, | xii. 3 |
| XXXVII. | Troy, N. Y., | October, 1883, | xii. 175 |
| XXXVIII. | Cincinnati, O.,* | February, 1884, | xii. 447 |
| XXXIX. | Chicago, Ill., | May, 1884, | xiii. 1 |
| XL. | Philadelphia, Pa., | September, 1884, | xiii. 285 |
| XLI. | New York, N. Y., | February, 1885, | xiii. 585 |
| XLII. | Chattanooga, Tenn., | May, 1885, | xiv. 1 |
| XLIII. | Halifax, N. S., | September, 1885, | xiv. 307 |
| XLIV. | Pittsburgh, Pa., | February, 1886, | xiv. 587 |
| XLV. | Bethlehem, Pa., | May, 1886, | xv. |

* Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

† Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

# PUBLICATIONS.

The publications of the Institute comprise:

1. The minutes of the Proceedings of each Meeting, published in pamphlet form.

2. Such of the papers presented or read by title at each Meeting as are furnished by the authors and approved by the Council for full publication. (In nearly all cases in which papers, the titles of which appear in the Proceedings, are not subsequently published, they have been withdrawn by the authors.) These papers are published separately in pamphlet form, and are marked "Subject to Revision."

3. Annual volumes of *Transactions*, containing the list of officers and members, rules, etc.; the Proceedings and the papers, *revised for final publication.* (In this revision after the preliminary publication, authors are permitted to use the largest liberty; and the changes and additions made in papers are sometimes important. It should be borne in mind, by those who study or quote a paper in the preliminary edition, that they may not have in that form the ultimate and deliberate expression of the author's views. It should be added, however, that in the majority of cases there is no essential change, the correction of typographical errors and additions of later information being the usual alterations.)

4. Special editions of separate papers, for which there is demand. These are fully revised, and usually issued in pamphlet covers.

5. Books. (Under this head the only publications thus far have been an Index to Vols. I. to X. inclusive, a Glossary of Mining and Metallurgical Terms, and a Memorial of Alexander Lyman Holley.)

All the foregoing publications are sent free to members and associates *not in arrears at the time of publication.* They are also for sale at the office of the Secretary, or are sent to purchasers by mail or express, charges paid, on receipt of the price by the Secretary, as follows:

Classes 1 and 2, above mentioned,—price not uniform—a small sum, in no case exceeding 20 cents per copy, to cover cost of printing, storage, clerk-hire, postage, etc.

Class 3 (*Transactions*), at $5 per volume in paper covers, or $6 bound in half-morocco.

Class 4. This class now includes "Steel Rails" (Papers by Messrs. Sandberg, Dudley and Holley, and discussions at two meetings in 1881, from vol. ix. of the *Transactions*), price $1; "Technical Education"

(Papers and discussions at the XVIIth [Philadelphia] meeting, in 1876 —mostly not in the *Transactions*), price 50 cents; "The Law of the Apex" (including the Appendix), by R. W. Raymond, price 25 cents; "List of Members, Rules, etc.," price 25 cents.

Class 5. Index to Vols. I. to X., inclusive, of the *Transactions*, price, in paper covers, $1; in half-morocco, $2. "Memorial of Alexander Lyman Holley," in cloth, with frontispiece-portrait, price $2. "Glossary of Mining and Metallurgical Terms," by R. W. Raymond (from vol. ix. of the *Transactions*), in cloth, price 50 cents.

All communications and remittances should be addressed tc R. W. Raymond, Secretary, P. O. Box 223, New York City.

# RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1880, and FEBRUARY, 1881.

---

## I.

### OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

## II.

### MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council, and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versa*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

## III.

### DUES.

The dues of members and associates shall be ten dollars per annum, payable in advance at the annual meeting; *Provided*, that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annual meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided*, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

## IV.

### OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appoint-

ment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

## V.

### ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting: *Provided*, that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

## VI.

### MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Two other regular meetings of the Institute shall be held in each year, at such times and places as the Council shall select, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of a majority of the members then present. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

## VII.

### PAPERS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

## VIII.

### AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

# PROCEEDINGS

OF THE

# XLIId (CHATTANOOGA) MEETING.

*MAY, 1885.*

VOL. XIV.—1

## *PROCEEDINGS OF THE FORTY-SECOND MEETING, CHATTANOOGA, MAY*, 1885.

### LOCAL COMMITTEES.

*Committee of Arrangements.*—H. S. Chamberlain, *Chairman;* M. I. Chapman, *Secretary;* M. Grant, Louis S. Colyar, Hugh Whiteside, John C. Griffiss.

*Committee on Entertainment and Excursions.*—H. Clay Evans, *Chairman;* M. Grant, J. L. McCollum, W. W. Yonge, Creed F. Bates.

*Citizens' Reception Committee.*—J. T. Wilder, *Chairman;* Garnet Andrews, J. E. McGowan, Tom Fort, D. P. Montague, M. J. O'Brien, Xen. Wheeler, S. R. Read, Robert Morrison, J. M. Duncan, W. E. Baskette, E. F. Sevier, Edward Doud, J. T. Hill, S. B. Lowe, C. E. James, W. F. Fischer, T. H. Payne, H. M. Wiltse, Dr. P. D. Sims, Major W. R. King, George E. Downing, Z. C. Patten, D. Woodworth, Jr., D. B. Loveman, John A. Hart, M. H. Clift, G. M. D. Heard, S. A. Key, J. M. Vernon, A. S. Ochs, T. G. Montague, W. S. Marshall, Dr. G. A. Baxter, H. F. Temple, T. A. Snow, W. W. Jackson.

*South Pittsburg.*—A. M. Shook, Superintendent Lodge, John Frater.

*Rockwood.*—M. M. Duncan, D. T. Peterman, John Patton.

*Dayton.*—John H. Ferguson, W. C. Gardenhire, Harry Hargraves.

*Headquarters.*—Stanton House, Chattanooga.

The opening session was held Tuesday evening, May 19th, in the hall of the Iron, Coal, and Manufacturers' Association, Nos. 12 and 14 East Ninth Street, Chattanooga. The hall was beautifully decorated with flowers. Captain H. S. Chamberlain, Chairman of the Local Committee of Arrangements, called the meeting to order, and introduced General J. T. Wilder, who delivered a brief address, cordially welcoming the Institute, in behalf of the city, on its second visit to Chattanooga, and giving, with the aid of the large geological map of the Iron, Coal, and Manufacturers' Association, a graphic and interesting explanation of the geological, topographical, and industrial conditions of the Tennessee region.

President J. C. Bayles, after acknowledging the hearty greeting thus extended, proceeded to address the Institute as follows:

GENTLEMEN OF THE INSTITUTE: The very interesting and remarkable development of iron manufacture in the South, since our meeting in this city seven years ago, suggests some thoughts which seem to me appropriate to the time and place, as a prelude to the more formal business which awaits our attention. I shall consider

briefly some of the aspects of Southern industrial progress as they present themselves to my mind.

In the following table, prepared from official sources, is shown the iron production of what is known as the Chattanooga District, including Southeastern Tennessee, Georgia, and Alabama, from 1878, the year of our first meeting in the South, to and including 1884:

| | Bituminous. Tons. | Charcoal. Tons. | Total. Tons. |
|---|---|---|---|
| 1878, | 48,469 | 26,496 | 74,965 |
| 1879, | 67,998 | 36,124 | 104,122 |
| 1880, | 113,695 | 45,014 | 158,709 |
| 1881, | 146,220 | 57,625 | 203,845 |
| 1882, | 184,090 | 71,106 | 255,196 |
| 1883, | 246,063 | 70,430 | 316,493 |
| 1884, | 279,047 | 69,063 | 348,110 |

The increase in the number of blast furnaces in the Chattanooga district, the limits of which I have already defined, is shown in the following table, giving the number at the close of each year since 1872:

| | Bituminous. | Charcoal. | Total. |
|---|---|---|---|
| 1872, | 2 | 14 | 16 |
| 1873, | 4 | 18 | 22 |
| 1874, | 5 | 23 | 28 |
| 1875, | 9 | 21 | 30 |
| 1876, | 9 | 19 | 28 |
| 1877, | 9 | 19 | 28 |
| 1878, | 9 | 18 | 27 |
| 1879, | 12 | 19 | 31 |
| 1880, | 13 | 18 | 31 |
| 1881, | 13 | 19 | 32 |
| 1882, | 13 | 15 | 28 |
| 1883, | 18 | 15 | 33 |
| 1884, | 19 | 18 | 37 |

Total annual capacity in 1872, say, 50,000 net tons, an average of 3125 tons per furnace. Total annual capacity in 1884, 565,000 net tons, an average of 15,300 tons per furnace.

The pig-iron production of the territory south of Pennsylvania and Ohio, exclusive of Missouri, for five years ending with 1884, is shown in the following table:

| States. | Net tons. | | | | |
|---|---|---|---|---|---|
| | 1880. | 1881. | 1882. | 1883. | 1884. |
| Alabama, | 77,190 | 98,081 | 112,765 | 172,465 | 189,664 |
| Virginia, | 29,934 | 83,711 | 87,731 | 152,907 | 157,483 |
| Tennessee, | 70,873 | 87,406 | 137,602 | 133,963 | 134,597 |
| West Virginia, | 70,338 | 66,409 | 73,220 | 88,398 | 55,231 |
| Kentucky, | 57,708 | 45,973 | 66,522 | 54,629 | 45,052 |
| Georgia, | 27,321 | 37,404 | 42,440 | 45,364 | 42,655 |
| Maryland, | 61,437 | 48,756 | 54,524 | 49,153 | 27,342 |
| Texas, | 2,500 | 3,000 | 1,321 | 2,381 | 5,140 |
| North Carolina, | . . . | 800 | 1,150 | . . . | 435 |
| Total, | 397,301 | 471,540 | 577,275 | 699,260 | 657,599 |

The coal production of Georgia, Alabama, and Tennessee was 144,418 tons in 1870, and, approximately, 3,400,000 tons in 1884. For the entire South it was 3,192,300 tons in 1870, and 10,844,000 tons in 1884.

The progress of the South, is not, however, confined to mining and iron-making. A southern statistical authority, the Baltimore *Manufacturers' Record*, in its issue of January 10, published a list of new manufacturing and mining enterprises organized in the South during 1884, showing that the capital, including capital stock, of incorporated companies was $105,000,000; and a similar report for the first three months of 1885 gives $21,000,000. These figures are perhaps misleading, as due allowance is not likely to be made for the capitalization of small enterprises on a large nominal basis. Some of these companies may never carry out the objects for which they were organized, and others may not issue the full amount of stock; but these statistics show a very great activity in Southern manufacturing and mining enterprises—greater by far than is generally supposed. In 1879 the assessed value of property in the South was $2,184,000,000; in 1884 it was $2,980,000,000, an increase of $800,000,000. In 1884 the Charleston, S. C., *News and Courier* made a careful and exhaustive investigation of the manufacturing and mining interests of South Carolina, taking up every section of every county in the State. According to this report, which has everywhere been accepted as quite trustworthy, the aggregate value of the products of all manufactures in that State in 1883 was $32,324,404, and of mines $2,440,000, against $16,738,008 and $1,180,805 as the value of the products of manufactures and mines,

respectively, during the census year 1879–80. And yet South Carolina has not made as much advance in these industries since 1880 as Virginia, North Carolina, Georgia, Alabama, Kentucky, or Tennessee. A complete census of the industrial interests of the South in 1885 would be a revelation.

It is not my purpose, however, to present even such statistics as are available relating to industrial development in the Southern States. In the few minutes at my command I can consider only very briefly the economic aspects of iron-making in the South, and especially in this district, already of national importance as a center of production. The fact that the South has many and conspicuous natural advantages favorable to cheap and abundant iron production, will be conceded without argument. But one does not need to be a very close student of industrial statistics to discover that it is possible to overestimate the importance of natural advantages. The history of Great Britain—for the past quarter of a century largely dependent upon advantages acquired through superior commercial enterprise—illustrates this in a very striking manner. Elsewhere we find examples showing that, in spite of natural disadvantages so obvious that one may well wonder at the courage shown in beginnings made under such adverse circumstances, great industrial developments are possible, and that with such seemingly artificial developments the competition of natural advantages is attended with many discouragements.

In her wealth of contiguous ores and fuels the South can justly claim such advantages as might be sought in vain almost anywhere else. That these advantages have told heavily in her favor, and with greater or less weight against less favored sections, one need but glance at at our iron-trade statistics to see. But, notwithstanding all that Nature has done for the South, she has not forgotten the law of compensations, which may be traced in all her open-handed beneficence. Even here the wheel of fortune does not turn in anti-friction bearings, and experience has already shown that in the South, as elsewhere, nature has left a good deal to be done by skill and enterprise; that here, as elsewhere, the conditions of success must be attained by means very similar to those which are more obviously necessary where nature has been less generous in dispensing her favors. If we dismiss from mind all the sensational stories which from time to time have spread a more or less modified consternation among Northern iron-makers, we may safely count upon the assent of conservative Southern opinion to the state-

ment that probably there has been very little profit realized in selling Southern irons for less than the admitted cost of competing Western and Northern irons, in Western and Northern markets.

The question of the cost of pig-iron is one of first interest to every one identified with enterprises promotive of the development of the country. The elements which enter into the manufacture of pig-iron are so few, and the methods of its production are so generally known, that tabulated statements of cost are exceedingly common. Many such statements get into print, and, whether they are authentic or not, they are used for purposes of illustration or comparison for months or years after their first appearance. Often they are purely speculative and represent what the poet has delicately described as "large desires with most uncertain issues." They are usually based upon the prices at which iron is to be made in furnaces not yet built; but if these hypothetical furnaces are located in the Lehigh Valley, in the Straitsville district, in Virginia, at Chattanooga, or at Birmingham, such a tabulation of cost items is made the basis of all sorts of comparisons with other districts. The older and less trustworthy the statement, and the more sensational its character, the more often it is relied upon to prove the superior facilities for the manufacture of pig-iron in some undeveloped region. I remember very well a pamphlet issued a few years ago, when costs were very high and prices enormously inflated, in which the cost of pig-iron on the Lehigh, on the Susquehanna and at Pittsburg was given, in comparison with figures, principally conjectural, for Virginia and other Southern States. Its object was to show how much more cheaply pig-iron could be produced in the South than in the old producing districts of the North. The figures served their purpose at the time, but since then the cost of iron-ore and the wages paid for labor have been greatly reduced; yet we still find these old tables of the cost of pig-iron on the Lehigh, on the Susquehanna, and at Pittsburg, marshalled in line with conjectural statements of the cost of pig-iron in undeveloped districts, just as though there had been no change in the elements of cost for four years. A little over a year ago Mr. J. B. Morehead, of Conshohocken, Pa., submitted to the Ways and Means Committee an authentic statement of the average cost of producing pig-iron in the Schuylkill Valley, which he showed was about $18.30. This statement has been published widely, and was received without criticism. Considered in connection with the prices of raw materials as they ruled when he made

up his statement, it is probably as nearly correct as as it can be made, but the changes which have since taken place, affecting the cost of ore, coal and labor, have already destroyed their value for purposes of present comparison. We need not be surprised, however, to see these figures used for many years as showing how much more cheaply pig-iron can be produced in certain remote and undeveloped districts than in the Schuylkill Valley.

If we carefully examine the conditions existing in one of the most favored and promising districts of the South, we find that it is possible to exaggerate the local advantages even without the intention of so doing. When the red fossil ores of Alabama were first used, they were taken from along the Red Mountain outcrop. They were easily and cheaply mined, and averaged nearly, if not quite 50 per cent. of metallic iron. In estimating the cost of producing iron from these ores it was assumed that 2 tons of ore to the ton of iron would be needed, and that the ore at furnace would not cost more than 60 cents per ton. But of this surface-ore the quantity is comparatively limited. To secure a supply, mining below the surface is necessary, and as we go deeper we find that the ore becomes harder and more difficult to mine, as well as leaner in iron, averaging only about 40 per cent. When operations began a good miner could easily mine 8 to 10 tons of the soft surface ore a day without explosives, but it requires a good hand to mine 4 tons of the hard ore in a day, even with a liberal use of 40-per cent. dynamite. Consequently, instead of making a ton of iron with 2 tons of ore, costing $1.20, it requires 2⅔ tons of ore, costing about $2.40 per ton of iron. For furnaces so situated that a railroad haul is necessary 25 cents per ton must be added, bringing the cost of ore up to about $3 per ton of iron, or $1.80 more than the original estimates. There is plenty of ore in Red Mountain, but it is not all available. Its quality varies as much as its quantity. Much of it is so silicious as to have no present value. According to the best information I can gain, the red fossil ores used at all the coke-furnaces in Alabama carry an average of 17 per cent. silica, and the percentage increases as greater depths are reached. The surface-ore contains but little lime, while the hard ore contains from 15 to 30 per cent. In this variation is found the explanation of much of the difficulty experienced by furnace managers in Alabama. The greatest care is necessary to keep the surface-ore and the hard ore separate, and the burden must be changed frequently. Hence lime sets and scaffolds are very common, and the time lost by reason of these almost una-

voidable accidents would turn a Northern furnace manager's hair gray in a very brief period.

The fuel supply of this favored district is from the Pratt seam. When free from slate and dirt the coal is good and produces a lustrous medium coke, but in the shape in which it mostly reaches the furnaces the coke is not a first-class furnace fuel; and considerably more than the originally estimated quantity is needed to produce a ton of iron. It has been stated that iron has been made with 1½ tons of this coke, but I do not think the statement has been substantiated. It probably takes 1¾ tons, to which must be added fuel burned under boilers and for other purposes, bringing the average up to 2 tons of coke per ton of iron.

Between the ore on one side and the coal on the other lies plenty of limestone—conveniently near, but, unfortunately, most inconveniently placed. In fact, the whole valley is full of limestone, much of it of superior quality. It is not, however, available for use in the furnaces of the district we are considering. It is all standing on edge, and the limestone used is obtained from a distance of 30 miles from the center of iron production, and is delivered by rail, costing 85 cents per ton of 2240 pounds.

The labor question is a troublesome one. The supply is abundant, but it is ignorant and unintelligent. Common labor commands $1 per day, and other labor is paid in proportion; but constant and strict supervision is necessary. The cost of labor at furnaces varies, I am told, from $2 to $2.50 per ton of iron. Perhaps $2.50 would be a fair average for labor and salaries.

Taking the facts as they are, I have the best and most intelligent, as well as the most conservative local authority for calculating the cost of iron-making at the point where the natural advantages seem to be greatest, as follows:

| | |
|---|---|
| 2¾ tons ore at $1.25, | $3.00 |
| 2 tons coke at $2.50, | 5.00 |
| 1 ton limestone at 85 cents, | 85 |
| Salaries and labor, | 2.50 |
| Interest and expenses, | 50 |
| Repairs and replacement, | 50 |
| Total, | $12.35 |

In this the average cost of coke is underestimated: $2.75 per ton would be nearer correct than $2.50, waste included.

I am aware that, in calculating the cost of iron, interest is usually omitted, but in the judgment of all skilled accountants interest is as

much a part of cost as materials, even when it does not have to be paid for the use of money borrowed on bonds or paper. Capital which does not earn interest is not invested, but sunk or locked up.

The average cost of getting this iron to market, including selling commissions, may be placed at $4. There is nothing in this total of, say, $16, to keep within safe bounds, to discourage the Southern iron maker, nor to alarm the producers of other sections. Pig iron of satisfactory quality can be made as cheaply at a great many favorable points North and West.

Since these figures were prepared I have had opportunity to examine critically the remarkable tables in the report on the "Consumption of Iron Ore and Fuel in the Production of Iron and Steel in 1884," by Mr. George W. Cope, Secretary of the American Iron and Steel Association. The correctness of these figures is not likely to be impeached, as they are compiled from the best obtainable data. They show that in Pennsylvania the average consumption of ore per ton of iron produced is 1.83 tons, which gives 54.7 per cent. as the average yield in metallic iron. For the whole United States the average is 1.87 tons of ore per ton of iron produced, giving an average of 53.4 per cent. of iron. For Tennessee, Georgia, Alabama, and North Carolina, the average consumption of ore per ton of iron is 2.31.5 tons, averaging 43.2 per cent. iron. From this it appears that Southern ores yield in the furnace 10.2 per cent. less iron than the average of the ore used in all the furnaces of the country, and that it requires .44 ton more ore than the national average to make a ton of iron in the South. The fuel comparison is equally surprising. The general average consumption of coke per ton of iron is 1.31 tons. This figure is reached by making due allowance for the coke equivalent of raw bituminous coal used, which in Mr. Cope's tables is counted as coke. In Tennessee, Georgia, Alabama, and North Carolina, the average coke consumption per ton of iron is 1.48 tons. Recapitulating these figures we find that in so much of the South as includes Tennessee, Georgia, Alabama, and North Carolina, the ore runs 10.2 per cent. in iron below the average of ores used in the United States, that .44 ton more of ore is needed to the ton of iron made, and that the coke consumption to the ton of product is .39 ton greater. What then, it may be asked, becomes of natural Southern advantages? The answer is that it is found in the contiguity of ores and fuel. The average of ores and fuels together per ton of iron produced is 3¼ tons for the whole country. If we knew the average haul per ton of material charged we should

know just how far the advantage of the Southern furnaces in this item of costs offsets the disadvantages noted. Probably a balancing of the two sides of the account would show a credit for the Southern furnaces large enough to fairly offset, at least, the heavier transportation charges borne by their product in reaching a market. I am sorry that these figures are not available, as they are the items which belong on the credit side of the Southern account. I do not dare to risk any speculations concerning them without better data than I now have of average haul of materials and product, and average cost of transportation per mile.

Not being a maker of pig-iron, and having no local interests to serve, I do not hesitate to give it as my opinion that, while the South will undoubtedly increase in importance as a source of pig-iron supply, it is not destined to monopolize the business of iron making. The sharp competition of Southern irons in Northern and Western markets is already causing the conditions so to change as to effect an equalization of advantages. Ores, coal, and labor are cheapening where the demand for them is lessened by causes discouraging production, and they must advance in value where the demand for them is stimulated. The cost of freights will always be a protection to those making iron nearer the great centres of consumption, and will continue to represent at least the normal average advantage of the Southern furnaces in first cost. That there are many points in the North and West which are quite as advantageous for iron making as any in the South, all things considered, I fully believe. The only significance of this fact, however, as bearing upon the question of the future of the Southern iron industry, is that, if its production of iron is based upon the consumptive requirements of the rest of the country, a good deal of its furnace capacity may be expected to stand idle much of the time.

The hope of the South is in a larger local consumption of iron. Most of its pig-iron product now pays freight to Northern rolling-mills and foundries, and such part of it as is needed for Southern use pays a second transportation charge when returned in manufactured forms. In this respect Southern industrial development has not been uniform. Its permanent prosperity will be found in rolling-mills, machine shops, foundries, and manufacturing industries to consume its pig-iron and convert it into forms which will bear transportation better than raw materials. It is repeating the experience of the West, and let us hope that, like the West, its prosperity

will be built upon the substantial foundation of diversified industries.

The following papers were then read by the authors:

The Geology and Mineral Resources of the Sequatchie Valley, Tennessee, by W. M. Bowron, South Pittsburg, Tenn.

The Microscopic Structure of Iron and Steel, by F. Lynwood Garrison, Philadelphia, Pa.

Utilization of the Copper and Iron Sulphides of Virginia, North Carolina, and Tennessee, by C. R. Boyd, Wytheville, Va.

The Secretary read a communication from Mr. Samuel Noble, Anniston, Ala., inviting members to visit that place, and inspect the iron works and ore-deposits at Anniston and Clifton. (This invitation was accepted, after the close of the meeting at Chattanooga, by a number of members.)

The second session was held on Thursday morning, at the same place. After preliminary announcements, the following papers were read by the authors:

The Flow of Air and Other Gases in Pipes, by Frederick W. Gordon, Philadelphia, Pa.

A New Fire Brick Hot-Blast Stove, by Victor O. Strobel, Philadelphia, Pa.

The Durham Blast-Furnace, by B. F. Fackenthal, Jr., Riegelsville, Pa.

The Manufacture of Steel Castings, by Pedro G. Salom, Thurlow, Pa.

Pamphlets describing the natural resources and industries of Tennessee were presented to members by Professor H. E. Colton, of Chattanooga; and copies of a map, showing the iron and coal regions of Tennessee and Alabama, were distributed as a gift from the *Iron Age* of New York city. A collection of ores, fluxes, and fuels from the region was inspected by members in a room adjoining the hall.

The third session was held on Thursday afternoon, at the Stanton House. The following papers were read by the authors:

The Upper Measure Coal-fields of Tennessee, by Henry E. Colton, Chattanooga, Tenn.

A Simple Apparatus for Testing the Comparative Strength of Explosives, by S. Whinery, Somerset, Ky.

The Secretary read a supplementary paper on the Clapp and Griffiths Process, by Robert W. Hunt, Troy, N. Y.

Major W. R. King, U. S. Engineer Corps, read, by invitation, a paper on Experiments with Bolts and Screw-Threads.

The Secretary presented in printed form the following papers:

The New Mining Code of Mexico, by Richard E. Chism, Saltillo, Coahuila.

The Relative Value of Coals to the Consumer, by H. M. Chance, Philadelphia, Pa. (with a note in discussion, by J. P. Kimball, Bethlehem, Pa.).

The following papers were read by title:

Quicksilver-Condensation at New Almaden, by S. B. Christy, Berkeley, Cal.

Colored Mining Labor, by A. F. Brainerd, Birmingham, Ala.

Notes on Some American Ore-Deposits, by C. M. Rolker, New York city.

Treatment of Roasted Pyrites by the Longmaid and Claudet Processes for the Extraction of Gold and Silver, by Thomas Egleston, New York city.

The Straight or No-Bosh Blast-Furnace (supplementary paper), by W. J. Taylor, Chester, N. J.

The "Centennial" and "Lotta" Gold-Properties, Coahuila, by Dr. Persifor Frazer, Philadelphia, Pa.

The Influence of Temperature in Steel-Making upon the Behavior of the Ingots in Rolling, by John W. Cabot, Bellaire, O.

The Sulphide Deposits of South Iron Hill, Leadville, by Francis T. Freeland, Denver, Col.

Biographical Notice of Professor C. O. Thompson, by Philip W. Moen, Worcester, Mass.

The Iron Ores of Pictou County, Nova Scotia, a communication to the Secretary from E. Gilpin, Jr., Inspector of Mines, Halifax, N. S.

The Secretary read a letter from Mr. E. Gybbon Spilsbury, inviting members who were so disposed, to visit the Haile gold-mine in South Carolina, on their way home after the meeting.

The following gentlemen, proposed for election as members and associates and recommended by the Council, were elected:

HONORARY MEMBER.

Geheimrath Professor Dr. Hermann Wedding, . Berlin, Prussia.

MEMBERS.

| | |
|---|---|
| Anderson, J. F. T., | Tredegar Iron Co., Richmond, Va. |
| Bartlett, James H., | Standard Building, Montreal, Canada. |
| Chenhall, James W., | Anaconda, Montana. |
| Colyar, Louis S., | Chattanooga, Tenn. |
| Frossard, John D., | Montreal, Canada. |
| Hargreaves, Henry W., | Dayton, Tenn. |
| Hill, J. T., | Whiteside, Tenn. |
| Johns, L. W., | Pratt Mines, Ala. |
| Johnston, James, | 417 Straight Street, Paterson, N. J. |
| Leavens, H. W., | 411 Larimer Street, Denver, Col. |
| Lippincott, J. E., | Swifts I. and S. Mills, Cincinnati, O. |
| McLennan, J. S., | Sidney, Cape Breton, N. S. |
| Malo, Alberto, | Puente de Sta Ana, No. 6, Mexico, Mex. |
| Markle, Alvan, | Hazleton, Pa. |
| Miller, George S, | Benwood, W. Va. |
| Norton, S., | Burden, N. Y. |
| Pillsbury, D. B., | Whiteside, Tenn. |
| Powell, William H., | Belleville, Ill. |
| Rickard, Thomas, | 58 Lombard Street, London, England. |
| Rueger, R. C., | Anaconda, Montana. |
| Scovel, Minor, | Pittsburgh, Pa. |
| Shook, A. M., | Tracy City, Tenn. |
| Simpson, C. D., | Scranton, Pa. |
| Stockwell, N. S., | U. S. Patent Office, Washington, D. C. |
| Thropp, Joseph E., | Edge Hill, Pa. |
| Van Hise, C. R., | Madison, Wis. |
| Weimer, Asa A., | Lebanon, Pa. |
| Weimer, John A., | Lebanon, Pa. |
| Weston, Francis E., | Upland, Pa. |
| Wilder, J. T., | Chattanooga, Tenn. |

ASSOCIATES.

| | |
|---|---|
| Berry, Wilton G., | School of Mines, New York City. |
| Himrod, Charles, | 186 Dearborn Street, Chicago, Ill. |
| Osterheld, Th. W., | Yonkers, N. Y. |
| Walker, Joseph R., | Salt Lake City, Utah. |

Mr. Curtis Alexander, associate, was, upon the recommendation of Council, made a member.

On motion of Mr. P. G. Salom, the following resolution was unanimously adopted:

*Resolved*, That the Secretary is hereby instructed to express to the citizens and corporations of Chattanooga and vicinity, and to the members of the Local Committees, the thanks of the Institute for courtesies extended to its members, and hospitable and efficient arrangements made for their comfort and entertainment.

The President then declared the meeting adjourned.

## EXCURSIONS AND ENTERTAINMENTS.

Wednesday, May 20th, was occupied with an excursion to the furnaces of the Tennessee Iron and Coal Company at South Pittsburgh, and the iron mines of the same company at Inman, Tenn. The trip to South Pittsburgh was made on the steamer "Throop," and the return by rail. Luncheon was served on the steamer. The weather was favorable, and the lovely scenery of the Tennessee River and Cumberland Mountain was fully appreciated by the Northern visitors.

Heavy rains on Thursday prevented the projected excursion to the National Cemetery, and other points of interest and beauty around Chattanooga; but Citico Furnace and one or two other manufacturing establishments were rapidly inspected.

On Thursday night a reception, tendered to the Institute by citizens of Chattanooga, was held in the parlors of the Stanton House at 9 o'clock, and a "strawberries and cream supper" was served at 10—a most seasonable and acceptable substitute for a formal "banquet." The occasion was thoroughly enjoyable and thoroughly enjoyed.

A delightful excursion was made on Friday to the furnaces and mines of the Roane Iron Company, at Rockwood, Tenn., and to the extensive Works and Improvements of the Dayton Coal and Iron Company, at Dayton, Tenn. The projected *fête champêtre* at Rockwood was prevented by showers; but the entertainment under roof was brilliantly successful. At Dayton also, the party was received with overflowing hospitality.

On Friday night, a party of members and guests, occupying two special cars, went by rail to Birmingham, Ala., where furnaces, coal and iron mines, etc., were visited, in company with a large delegation from the Commercial Convention, which had just adjourned in Atlanta, Ga.

Smaller parties subsequently visited Anniston, Ala., the New Orleans Exposition, and other points in the South.

The following names were registered on the Secretary's list at headquarters:

## MEMBERS AND ASSOCIATES PRESENT.

C. M. Atkins, Jr.
J. Herbert Bartlett.
J. C. Bayles.
W. M. Bowron
C. R. Boyd.
Cabell Breckenridge.
Henry W. Bulkley.
C. Cadle, Jr.
H. S Chamberlain.
H. E. Colton.
T. B. Comstock.
A. B. Cornell.
M. M. Duncan.
W. F. Durfee.
W. E. C. Eustis.
B. F. Fackenthal, Jr.
M. Fackenthall.
E. M. Ferguson.
H. S. Fleming.
E. L. Foote.
F. L. Garrison.
Frederick W. Gordon.
G. C. Hewett.
Frank A. Hill.
Charles Himrod.
William S. Hungerford.
E. S. Hutchinson.
J. E. Johnson.
Joseph C. Kent.
James F. Lewis.
M. J. Lunn.
J. R. Maxwell.
James Neilson.
William G. Neilson.
Edward Nichols.
George Ormrod.
R. W. Raymond.
P. G. Salom.
A. W. Sheafer.
Alexander Stransz.
Victor O. Strobel.
Edwin Thomas.
Samuel Thomas.
Asa A. Weimer.
John A. Weimer.
S. Whinery.
J. T. Wilder.
John Wilkes.
David Williams.
J. P. Witherow.

# PAPERS

OF THE

# XLIId (CHATTANOOGA) MEETING.

*MAY, 1885.*

## *THE RELATIVE VALUE OF COALS TO THE CONSUMER.*

*Illustrated by a Comparison of the Freeport Lower* (D) *and Kittanning Lower* (B) *Coals.*

BY DR. H. M. CHANCE, PHILADELPHIA, PA.

Should inferior coals, in open market at competing points, command a price equal to that of the superior coals with which they come into competition?

This query seems absurd and the answer seems obvious. It might readily be supposed that the better coals always command a higher price, but every dealer knows that such is not the case, and that even when current prices are shaded on second or third grade coals, the difference in price is rarely commensurate with the difference in quality.

To the consumer this must be a matter of real practical importance—of dollars and cents—and it seems somewhat strange that it has not received more attention from practical men of business. Ironmasters buy their ore by the unit of iron contained in the ore, and the value of copper, lead, tin, manganese, silver and lead ores is estimated in the same way; but it is evident that this method could not successfully be applied to coal except in a broad and general manner, for the value of a coal is not wholly dependent upon the percentage of combustible matter, but varies with the relative percentages of water, sulphur, and ash.

Thus, two coals showing respectively

| | | |
|---|---|---|
| Combustible matter, | 95.00 | 95.00 |
| Water, | 0.50 | 2.50 |
| Sulphur, | 0.50 | 0.50 |
| Ash, | 4.00 | 2.00 |

will not have the same value as fuels, and as each of these impurities may vary between wide limits, the application of the analytical method is beset with many difficulties. However, if it is restricted to coals with small water percentages and only used to determine the *relative* values of coals having approximately the same fuel ratio (ratio of fixed carbon to volatile hydrocarbons), the results should

be as satisfactory and reliable as any other known method. It is true that by this method the sulphur is treated simply as an impurity, but as we have no means of estimating the damage resulting from any specified sulphur percentage, it is not possible to express in figures what concession should be made in the price of any coal containing a certain sulphur percentage to cover the damage resulting from its use.

Again: the relative proportions of volatile matter and fixed carbon, the structure of the coal, and its behavior in the fire, are all variable factors of great importance to the consumer, for it does not follow that coals showing the same percentage of combustible matter are of equal calorific energy, or equally well adapted to meet some special trade requirement.

But, other things being equal, it is evident that coals containing large percentages of water, sulphur, or ash, should not command a price equal to those low in impurities. However this may be, dealing with existing conditions at the principal coal markets, we find a remarkably different state of affairs.

The consumer often appears indifferent to the quality of the coal he is purchasing, regarding concessions as to time, or a slight shading of the price, of more importance than the quality of the coal. If desiring a coal for use under boilers, he seems satisfied in obtaining a "strong steam coal," without stopping to inquire how much more steam might be made with the same or a less quantity of coal lower in water and ash, or how much less damage to grates and boilers would result from a coal lower in sulphur.

In reality I believe that this indifference is only apparent, and not real, and that it arises from a conviction that there is no trustworthy means of estimating the relative values of the different coals offered for sale. Private analytical work being too costly, and steaming tests more so, there seems to be no available data to guide in determining what coal to purchase and how much above or below current quotations should be paid for any particular coal.

It does not seem beyond the province of the United States Geological Survey and the various State surveys to enter upon investigations having as their object a careful differentiation of the relative values for different purposes of the various coals sold in the market. To accomplish this end it would seem that the samples analyzed and experimented with should be obtained at the point of delivery, just as the samples of phosphate fertilizers are now obtained by the State chemists for analysis.

In the absence of such comprehensive investigations it would still seem that the analyses made by the different State geological surveys would be of great assistance to the consumer in determining the relative value of different coals; but the specific facts needed for this purpose are commonly scattered through voluminous reports through which he has neither the time nor inclination to search; the analyses are often designated by the local name of the mine, the market name or the owners' or operators' name being omitted, or one substituted for the other; differences in the geological nomenclature of coals in adjoining districts constitute an almost insuperable obstacle in attempting to make any generalizations or comparisons, and the attempt (if made) to use the recorded facts is commonly abandoned in disgust, and the consumer falls back upon his own experience and that of others, and the market reputation of the coal as his only guides.

The reports of the Second Geological Survey of Pennsylvania contain a great mass of material that may be used to much advantage, when properly tabulated to facilitate comparisons; but recorded as it is, in "reports of progress," its utility is lessened by the metamorphosis through which the coal measure nomenclature has passed in advancing from that of the First Survey to that finally adopted in the latest reports ($H_6H_7T_4R_2V_2$), and also by some mis-identifications of beds made in the earlier reports. The fact that this material cannot successfully be used until it has been revised and placed in tabular form is amply proven by two papers lately presented to the Institute by Dr. James P. Kimball,* in which an attempt is made to show the character of certain beds in different districts by analyses selected from the State reports. In the latter paper a great group of mines opened on the Freeport Lower Coal (D), is referred to the Kittanning Upper Coal (C'). Hence it appears that even with the minute and careful study of these reports evidently made by Dr. Kimball, the results cannot safely be used in this way without a personal inspection of the ground—a re-survey in fact of certain parts;—of how much less use then must they be to the man of business who has neither the time nor inclination for such an investigation. It would seem that only those familiar with the practical work of the survey in all of its stages can properly rearrange and tabulate the analyses for practical use.

* Differential Sampling of Coal Seams, 1883, *Trans.*, vol. xii., p 317, and the Quemahoning Coalfields of Somerset County, Pa., 1884, *ibid.*, p. 468.

In the tables annexed to this paper I have attempted to show what might be accomplished if this work was carefully and thoroughly extended to cover the whole State. The analyses of the two principal coal beds worked in Clearfield, Centre, Clinton, Jefferson, Cameron, Elk, Clarion, Northern Armstrong and Cambria counties are arranged in tabular form and the general averages deduced from them are in sufficient contrast to merit the attention of all concerned in both mining and consuming coal from these counties. The figures in the columns marked "Fuel" show the sum of fixed carbon and volatile hydrocarbons—in other words, the combustible matter. The averages deduced from these tables to show the general character of the two beds are as follows:

FREEPORT LOWER COAL.—BED D.

| Locality. | Fuel. | Sulphur. | Ash. |
|---|---|---|---|
| Average for Clearfield County, . . . | 94.91 | 0.59 | 3.55 |
| Average for Jefferson County, . . . | 93.94 | 1.00 | 3.76 |
| Average for Clarion County, . . . . | 93.41 | 1.19 | 4.10 |
| General Average Composition, . | 94.20 | 0.90 | 3.75 |

KITTANNING LOWER COAL.—BED B.

| Locality. | Fuel. | Sulphur. | Ash. |
|---|---|---|---|
| Average for Allegheny Mountain group, | 89.77 | 1.68 | 7.98 |
| Average Clarion County group, . . . | 90.31 | 2.12 | 6.28 |
| Average Elk County group, . . . . . | 89.02 | 2.77 | 7.15 |
| General Average Composition, . | 89.76 | 2.10 | 7.08 |

The percentage of water does not vary materially in the averages, that of bed D being 1.17 and of bed B 1.06.

These analyses plainly show a marked difference in the quality of coal mined from these two beds, and this difference is sufficiently great to be of considerable commercial importance.

Care has been taken to exclude from these tables all analyses of beds the identification of which does not seem absolutely certain. A

very few mines in this area—perhaps a dozen in all—are not shipping coal from either of these two beds, being opened on the Freeport Upper, Kittanning Upper, Clarion, Brookville, or Conglomerate coal beds, the latter principally in Elk and McKean counties. The output from these mines (to which these conclusions do not apply) is quite insignificant compared to that from the two beds here discussed.

An inspection of the tables will show that not one of the twenty-five analyses of the Kittanning Lower coal (B) reaches the *fuel average* of the Freeport Lower bed (D); that only two* show less sulphur than the *sulphur average* of D, and that none show an ash percentage as small as the Freeport Lower *ash average*. On the other hand, of the fifty analyses of Freeport Lower (D) coal, only one† shows as small fuel percentage as the Kittanning Lower (B) *fuel average*, none show as much sulphur as the *average* of the latter, and only two‡ show as much ash as the Kittanning Lower *ash average*.

The twenty-five analyses of the (nineteen mines) Kittanning Lower coal (B), with perhaps three exceptions,§ show coal objectionably high either in sulphur or ash, or in both.

Of the fifty analyses of the Freeport Lower coal (D) only two show objectionable ash and sulphur percentages, and, as has already been indicated, these percentages are due to a purely local condition of the bed where these samples were obtained.

It then seems safe to conclude that coal mined from the Freeport Lower coal—Bed D—in the area under discussion will, with rare exceptions, show:

| | |
|---|---|
| Fuel, | 92.00 to 96.00 per cent. |
| Sulphur, | 1.25 to 0.45 " |
| Ash, | 5.00 to 2.50 " |

And that coal mined from the Kittanning Lower coal—bed B—may commonly be expected to show:

---

* And one of these was sampled by the owners

† And at this colliery the condition of the bed is purely local.

‡ And at both these collieries the high ash percentage is limited to a very small area of the bed.

§ When two or three analyses are given of different benches of the same bed, no one of these is considered as representing the commercial analysis of the coal; an average must be obtained by combining them in like ratio with the thicknesses of the different benches,—of course in some cases the top or bottom bench is omitted as not taken out in mining.

| | | | |
|---|---|---|---|
| Fuel, | 87.00 to 92.00 | per cent. |
| Sulphur, | 3.00 to 1.00 | " |
| Ash, | 10.00 to 5.00 | " |

It appears that the poorest coal mined from the Freeport Lower (D) bed, when in normal condition, is, as shown by the analyses, about equal in quality to the best coal mined from the Kittanning Lower (B) bed.

These conclusions do not apply to the districts south and west from the area under discussion, for the character of both beds will doubtless be found to undergo some change in passing any considerable distance beyond the limits of this area, and even if their relative characters remained unchanged the conclusions here arrived at could not be of much service in other districts, because other beds assume greater prominence in these localities. Thus in the Johnstown district E (Freeport Upper) and C′ (Kittanning Upper) are more important; in Lawrence and Beaver counties C′ (Kittanning Upper) and C (Kittanning Middle) are mined; in Mercer the Sharon (Conglomerate) bed is largely worked, and so on; but it cannot be doubted that, if the method adopted in this paper was applied to other districts in this and other States, marked differences in the commercial value of coal mined from the different beds would be established.

In the absence of governmental work of this class, and in the overstocked condition of nearly all the principal markets, it is somewhat surprising that the companies mining and shipping the superior coals have not taken systematic action to control these markets in their own interest, to the exclusion of their less fortunate competitors, by supplying the consumer with information that would enable him to discriminate among the various grades offered for sale. Manufacturers of many articles adopt similar methods with advantage, and there does not appear to be any reason why such a plan might not result in benefit to both the producer and consumer of coal.

It does not seem difficult to foretell the probable ultimate effect of the adoption of such a plan, for discrimination by the consumer would inevitably lead to sharp cuts in the quotations of the inferior coals. Concessions in price sufficient to warrant the purchase of the inferior coals would destroy all possible chance of profit to the producers (unless located nearer market with lower railroad freight-charges than their competitors) and it would seem probable that in the operation of the law of the "survival of the fittest," producers of second and third grade coals would be crushed out of existence. In some cases, however, closer proximity to market or advantages de-

rived from competing transporting companies would enable the miners of inferior coals to make such concessions, control their own market, and reap handsome profits. Again, in those instances of coals inferior in composition but especially adapted to certain uses or to meet peculiar trade requirements, the poorer coal could not be displaced, but under such conditions this poorer coal is in reality the better article (for these special uses) and should command the highest price; here analyses (as commonly made) are almost worthless, and the practical test of experience destroys in a moment any relative valuations deduced from chemical composition.

Basing the relative value of a coal upon its percentage of combustible matter ("fuel"), the value is not exactly proportionate to this percentage; for a certain deduction is to be made to cover the increased cost of stoking and removal of the ash, since with every reduction in the percentage of combustible matter a correspondingly increased amount of coal must be burnt to make the same quantity of steam. If the cost of stoking a ton of coal be taken at $6\frac{2}{3}$ per cent. of the cost of the coal (and this is about what it will average with coal at $3.00 per ton and labor at $1.00 per day) and the cost of handling one ton of ash at double the cost of stoking one ton of coal, the following figures are obtained:

*Relative Value of Coals.*

| Fuel per Cent. | Increased Cost of Stoking and Removal of Ashes. | Value Ratio. | Fuel per Cent. | Increased Cost of Stoking and Removal of Ashes. | Value Ratio. |
|---|---|---|---|---|---|
| 100* | — 0.00 = | 100.00 | 87 | — 2 98 = | 84 02 |
| 99* | — 0.20 = | 98.80 | 86 | — 3.26 = | 82.74 |
| 98* | — 0.41 = | 97.59 | 85 | — 3.52 = | 81.48 |
| 97 | — 0.62 = | 96.38 | 84 | — 3.80 = | 80.20 |
| 96 | — 0.83 = | 95.17 | 83 | — 4.10 = | 78.90 |
| 95 | — 1.05 = | 93.95 | 82 | — 4.38 = | 77.62 |
| 94 | — 1.28 = | 92.72 | 81 | — 4.68 = | 76.32 |
| 93 | — 1.51 = | 91.49 | 80 | — 5.00 = | 75.00 |
| 92 | — 1.74 = | 90.26 | 79 | — 5 32 = | 73.68 |
| 91 | — 1.98 = | 89.02 | 78 | — 5.64 = | 72.36 |
| 90 | — 2.22 = | 87.78 | 77 | — 5.98 = | 71.02 |
| 89 | — 2.46 = | 86.54 | 76 | — 6.32 = | 69.68 |
| 88 | — 2.72 = | 85.28 | 75 | — 6.66 = | 68.34 |

As under varying conditions the cost of stoking and removal of ashes will vary between wide limits, these ratio values are appli-

* It will be understood that these high percentages are purely theoretical, and are here added only to complete the symmetry of the table.

cable to only a small number of cases, but the table indicates how any one may construct a similar table for any fixed cost of stoking and ash removal. Applying the ratios of this table to the general average fuel-percentages of the Freeport Lower (D) coal, and the Kittanning Lower (B) coal which may be taken at 94 (94.20) and 90 (89.76) per cent. respectively, and assuming the value of the former at $3.00 per ton, we obtain

92.72 : 87.78 : : $3.00 : $2.84

$2.84 as the relative value of the latter, but it must be remembered that another deduction should still be made on account of the objectionable sulphur-percentage of this Kittanning Lower coal, but it does not seem possible to determine how much the coal is thus reduced in value. However, we may safely assume that a margin of difference in price, averaging from 15 to 20 (if not more) cents per ton should exist to warrant the purchase of the inferior coal.

Having now considered the general average quality of coals mined from the two beds, it should be remembered that the coals of each class vary widely, and that between the poorer coals of the one and the better coals of the other, the margin is much smaller and might, perhaps, be in favor of the latter; but as the quality of the one in general is so much poorer than the other, the burden of proof must rest with the coal from the inferior bed, to show cause why it should not be classed commercially with those of the class to which it belongs geologically.

The analyses given in the following tables were made by Mr. A. S. McCreath and are recorded in his reports M, $M_2$, $M_3$. The letter and page of the geological reports in which they are published are given in parentheses after the name of each mine.

ANALYSES OF THE MOSHANNON OR FREEPORT LOWER COAL—BED D—IN CLEARFIELD COUNTY.

| | Name of Mine. | R. R. Outlet. | Fuel. | Water at 225° | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Davis—Goulich Twp., ($H_7$ 38) | | 94.81 | 0.64 | 23.01 | 71.80 | 0.55 | 4.00 | 5 miles from R. R. |
| 2. | Penn—Reakirt Bros. & Co., ($H_7$ 63) | P. R. R. | 94.66 | 0 81 | 20.64 | 74.02 | 0.51 | 4.02 | |
| 3. | Franklin—Kittanning C. Co., ($H_7$ 65) | do. | 93.72 | 1.94 | 22.72 | 71.02 | 0.54 | 3.78 | |
| 4. | do. do. do. (H. 30) | do. | 95.64 | 0.67 | 21.36 | 74.28 | 0.44 | 3.25 | |
| 5. | Eureka No. 1—Berwind, White & Co., ($H_7$ 66) | do. | 94.73 | 0.78 | 21.68 | 73.05 | 0.69 | 3.80 | |
| 6. | Webster No. 1—J. C. Scott & Son, ($H_7$ 67) | do. | 94.81 | 1.63 | 22.00 | 72.81 | 0·43 | 3.13 | |
| 7. | Stirling No. 1—R. H. Powel & Co., ($H_7$ 69) | do. | 95.62 | 0.71 | 23.40 | 72.22 | 0.53 | 3.14 | |
| 8. | Beaver Run—(Kendrick & Co)., (H. 34) | do. | 95 56 | 0.92 | 21.55 | 74.01 | 0.63 | 2.89 | |
| 9. | Old Moshannon—M. C. Co., ($H_7$ 70) | do. | 94 87 | 0.76 | 20.09 | 74.78 | 0.67 | 3.70 | |
| 10. | do. do. | do. | 94.27 | 1.10 | 23.07 | 71.20 | 0.61 | 4.02 | |
| 11. | Mapleton—Berwind, White & Co., ($H_7$ 73) | do. | 92.45 | 0.70 | 23.56 | 68.89 | 1.72 | 5.13 | |
| 12. | Logan—H. J. Smith & Co., ($H_7$ 74) | do. | 90.86 | 0.62 | 22.13 | 68.73 | 0.87 | 7.65 | |
| 13. | Laurel Run—Nuttall & Bacon, ($H_7$ 75) | do. | 95.61 | 0.80 | 23.26 | 72.35 | 0.59 | 3.00 | |
| 14. | Derby—Thos. Barnes, ($H_7$ 76) | do. | 89.50 | 0.41 | 22.81 | 66.69 | 1.79 | 8.30 | |
| 15. | Morrisdale—R. B. Wigton & Sons, ($H_7$ 79) | do. | 95 78 | 0.55 | 24.09 | 71.69 | 0 57 | 3.10 | |
| 16. | do. do. do. | do. | 96.20 | 0.56 | 25 19 | 71.01 | 0.59 | 2.65 | |
| 17. | Karthaus, | do. | 95.03 | 0.63 | 24.63 | 70.40 | 0.65 | 3.65 | Opened in 1884. |
| | Average, | | 94.36 | | | | 0.73 | 4.07 | |
| | Average for Clearfield County,* | | 94.91 | | | | 0.59 | 3.55 | |

* Omitting Nos. 12 and 14 as exceptional, the high percentage of impurities shown by these analyses being purely local.

ANALYSES OF THE FREEPORT LOWER COAL—BED D—IN JEFFERSON COUNTY.

| Name of Mine. | R. R. Outlet. | Fuel. | Water at 225° | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1. Reynoldsville C. Co.*—Sharp Mine, ($H_6$ 132) | Low Grade. | 94.72 | 1.57 | 33.43 | 61.29 | 1.06 | 2.66 | At Pancoast, main bench. |
| 2. do. do. | Div. A. V. R. R. | 94.03 | 1.32 | 31.44 | 62.59 | 0.89 | 3.77 | Upper bench, not worked |
| 3. Diamond—Diamond C. Co., ($H_6$ 134) | do. † | (88.13) | 1.19 | 32.81 | 55.32 | 2.28 | 8.40 | do. |
| 4. do. do. | do. † | (80.82) | 0.98 | 30.30 | 50.52 | 2.43 | 15.77 | Main bench, upper part. |
| 5. do. do. | do. | 94.55 | 1.12 | 33.86 | 60.69 | 1.28 | 3.05 | do. lower part. |
| 6. do. do. | do. | 94.16 | 0.95 | 35.13 | 59.03 | 1.44 | 3.18 | Main 5 ft. bench. |
| 7. Hoover—Ohio Mining Co., ($H_6$ 136) | do. | 91.78 | 0.96 | 32.68 | 59.10 | 1 06 | 6.20 | Main bench, upper part. |
| 8. do. do. | do. | 93.32 | 1.10 | 30.80 | 62 52 | 0.78 | 4.80 | do. middle part. |
| 9. do. do. | do. | 95.07 | 1.10 | 32.90 | 62 17 | 0.73 | 3.10 | do. lower part. |
| 10. Seley—Soldier Run, ($H_6$ 138) | do. | 91.08 | 0.85 | 31.20 | 59 88 | 1.37 | 6.70 | Main bench, upper part. |
| 11. do. do. | do. | 94.25 | 1.04 | 31.61 | 62.64 | 0.74 | 4.15 | do. lower part. |
| 12. Sprague, ($H_6$ 139) | | 94.05 | 1 43 | 31.94 | 62.11 | 0.53 | 3.99 | |
| 13. Strouse's, | | 93.84 | 1.30 | 30.22 | 63.62 | 0.76 | 4.10 | |
| 14. Hum's—Punxatawney, ($H_6$ 27) | R.& P R.R. | 95.40 | 0.92 | 35.44 | 59.96 | 0 85 | 2.83 | Main bench, upper part. |
| 15. do. do. | do. | 96.34 | 1.00 | 33.26 | 63.08 | 1.14 | 1.52 | do. lower part. |
| 16. Wingert—Punxatawney, ($H_6$ 29) | do. | 92.50 | 1.15 | 32.07 | 60.43 | 1.70 | 4 65 | |
| 17. Pantall—Punxatawney, ($H_6$ 30) | | 94.71 | 1.10 | 31.17 | 63.54 | 1.02 | 3.17 | |
| 18. Hawk—Elk Run, Punxatawney, | R. & P. R. R. | 91.07 | 0 95 | 33 55 | 60.52 | 1.17 | 3.81 | |
| 19. Huffman—Oliver Twp., ($H_6$ 62) | | 94.37 | 1.54 | 37.61 | 56.76 | 1.10 | 2.99 | |
| 20. Keslar—McCalmont Twp., ($H_6$ 69) | | 95.25 | 1.16 | 33.02 | 62.23 | 1.06 | 2.53 | |
| 21. Eshbaugh—Knox Twp., ($H_6$ 115) | | 92.99 | 1.39 | 38.27 | 54.72 | 1.53 | 4.59 | |
| 22. Patton—Washington Twp., ($H_6$ 169) | | 93.55 | 1.87 | 32.45 | 61.10 | 0.55 | 4.03 | |
| 23. Reynolds—Reynoldsville, (H. 157) | Low Grade. | 95.47 | 1.44 | 32.46 | 63.01 | 0.64 | 2.45 | |
| 24. Shiesley—Reynoldsville, (H. 158) | Div. A. V. R. R. | 94.49 | 1.60 | 30.70 | 63.79 | 0.64 | 3.27 | Main bench, upper part. |
| 25. do. do. | | 94.24 | 1.48 | 29.22 | 65.02 | 0.61 | 3.67 | do. lower part. |
| 26. Wachob—Punxatawney, (H. 169) | | 95.14 | 1.30 | 32.57 | 62.57 | 1.02 | 2.54 | |
| 27. McKee—Punxatawney, (H. 176) | | 91.55 | 1.05 | 33.15 | 58.40 | 1.30 | 6.10 | |
| 28. London—Reynoldsville, (H. 194) | A. V. R. R. | 93.54 | 1.15 | 27.70 | 65.84 | 0.93 | 4.38 | |
| Average for Jefferson County, | | 93.94 | | | | 1.00 | 3.76 | |

* Helm, Goodwill and F. Williams.

† Thrown out in averaging, as not representative of the quality of the Coal.

ANALYSES OF THE FREEPORT LOWER COAL—BED D—IN CLARION COUNTY.

| Name of Mine. | R. R. Outlet. | Fuel. | Water at 225° | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1. Fairmount Coal Co., ($V_2$ 101) | Low Grade. | 94.54 | 1.32 | 40.56 | 53.98 | 1.49 | 2.65 | |
| 2. do. | Div. A. V. R. R. | 95.03 | 1.70 | 38.93 | 56.10 | 0.60 | 2 67 | |
| 3. do | do. | 93.68 | 1.32 | 40.80 | 52.88 | 0.88 | 4.12 | |
| 4. Wilkins—Porter Twp., ($V_2$ 93) | | 93.51 | 1.64 | 37.15 | 56.36 | 1.16 | 3.73 | County bank. |
| 5. Smullen— do. | | 93.18 | 1.85 | 38.51 | 54.67 | 1.05 | 3.92 | do. |
| 6. Goheen's— do. ($V_2$ 90) | | 90.54 | 1.17 | 39.15 | 51.39 | 2.07 | 6.22 | do. |
| 7. Murphy—Toby Twp., | | *(88.75) | 4.77 | 35.12 | 53.63 | 1.10 | 5.38 | do. |
| Average in Clarion County, | | 93.41 | | | | 1.19 | 4.10 | |
| General Average Freeport Lower Coal, | | 94.20 | | | | 0.90 | 3.75 | |

* Water percentage doubtless due to some peculiarity in the sample.

ANALYSES OF THE KITTANNING LOWER COAL—BED B—IN CENTRE, CLEARFIELD, CLINTON, CAMBRIA, CLARION, NORTH ARMSTRONG, AND ELK COUNTIES.

| Name of Mine. | R. R. Outlet. | Fuel. | Water at 225° | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1. Snow Shoe—Mine No. 4, (H. 70) | P. R. R. | 87.81 | 0.75 | 23.44 | 64 37 | 0.99 | 10.45 | |
| 2. do. Midland M. Co., ($T_4$ 93) | | 89.33 | 0.72 | 23.55 | 65.78 | 0.79 | 9.16 | Sampled by owners. |
| 3. Powelton—R. H. Powel & Co., (H. 40) | P. R. R. | 94.11 | 0.54 | 22.56 | 71.55 | 1.08 | 4.27 | Upper bench. |
| 4. do do. | do. | 91.31 | 0.60 | 22.60 | 68.71 | 2.69 | 5.40 | Lower bench. |
| 5. Williamson—Philipsburg, (H. 56) | | 91.52 | 0.62 | 22.73 | 68.79 | 1.58 | 6.28 | Country bank. |
| 6. Lloydsville—Cambria Co., ($H_2$ 86) | Bell's Gap | 83.45 | 0.63 | 24.23 | 59.22 | 2.24 | 13.68 | Upper bench. |
| 7. do. do. | R. R. | 90.87 | 0.71 | 26.06 | 64.81 | 1.51 | 6.91 | Middle bench. |
| 8. do. do. | do. | 89.75 | 0.97 | 26.13 | 63.62 | 2.58 | 6.70 | Lower bench. |
| 9. Melon—Chest Creek, ($H_2$ 141) | | 89.28 | 0.85 | 22.59 | 66.69 | 3.13 | 6.74 | Country bank. |
| 10. do. do. | | 91.09 | 0.88 | 22.75 | 68.34 | 1.91 | 6.12 | Second sample. |
| 11. Merriman—Westport, ($G_4$ —) | P. & E. R. R. | 87.53 | 0.76 | 21.46 | 66.07 | 2.63 | 9.08 | Not developed. |
| 12. Fairmount Coal Co., ($V_2$ 105) | Low Grade. | 88.10 | 0.95 | 39.69 | 48.41 | 3.44 | 7.51 | Average slack coal. |
| 13. do. | Div. A. V. R. R. | 89.44 | 0.85 | 39.65 | 49.79 | 1.55 | 8.16 | Upper bench. |
| 14. do. | do. | 89.57 | 0.93 | 41.00 | 48.57 | 1 53 | 7.97 | Lower bench. |
| 15. Songer—Red Bank Twp., Clarion Co., ($V_2$ 110) | | 87.93 | 1.02 | 40.42 | 47.51 | 3.79 | 7.26 | Country bank. |
| 16. McCall—Perry Twp., do. ($V_2$ 121) | | 90.97 | 2.07 | 35.70 | 55.27 | 0 83 | 6.13 | do. |
| 17. Fox—Piney Twp., do. ($V_2$ 131) | | 91.28 | 1.47 | 41.35 | 49.93 | 2.07 | 5.18 | do. |
| 18. Sloan—Limestone Twp., | | 91.88 | 1.75 | 36.44 | 55.44 | 1.07 | 5.30 | do. |
| 19. Sligo Br. C. Co., ($V_2$ 83) | Low Grade. | 91.39 | 1.37 | 41.57 | 49.82 | 2.82 | 4.42 | |
| 20. Mahoning C. Co.—Armstrong Co., ($M_3$ 58) | A.V. R. R. | 92.24 | 1.18 | 42.55 | 49.69 | 2.00 | 4.58 | |
| 21. N. W. Mining & Ex. Co.—Elk Co., ($M_3$ 68) | P. & E. R. R. | 91.64 | 1.08 | 38.45 | 53.19 | 1.98 | 5.30 | |
| 22. St. Mary's C. Co.—Elk Co., ($M_3$ 69) | | 91.18 | 0.99 | 38.35 | 52.83 | 2.04 | 5.79 | Farmerdale Mine. |
| 23. do. do. | P. & E. R. R. | 84 98 | 1.19 | 33.99 | 50.99 | 3.12 | 10.71 | St. Mary's, east side. |
| 24. do. do. | do. | 87.30 | 1.05 | 39.30 | 48.00 | 3.32 | 8.33 | do. west side. |
| 25. Cascade—St. Mary's, ($M_3$ 70) | do. | 90.00 | 0.99 | 40.58 | 49.42 | 3.37 | 5.64 | |
| Average on Allegheny Mountain, | | 89.77 | | | | 1.68 | 7.98 | |
| Average of Clarion County group, | | 90.31 | | | | 2.12 | 6.28 | |
| Average of Elk County group, | | 89.02 | | | | 2.77 | 7.15 | |
| Average Kittanning Lower Coal, | | 89.76 | | | | 2.10 | 7.08 | |

It will be at once apparent that this method of determining the relative values of any two coals can only be useful when the ratio of the fixed carbon to the volatile hydrocarbons ("fuel-ratio") is nearly the same in both. The fuel-percentage of one of the Clearfield analyses Bed D, is 92.45, and that of an Armstrong County Bed B analysis 92.24, but the conclusion that these two coals were of about equal calorific energy would probably not be sustained by experience, for they vary greatly in their fuel-ratios, thus,

23.56 volatile matter + 68.89 fixed carbon = 92.45
42.55 " " + 49.69 " " = 92.24

and these two coals, although nearly equal in fuel-percentages may have very different values to the consumer. It is therefore assumed that in estimating relative values in this way it is always necessary to confine the comparisons to coals containing nearly the same relative percentages of volatile matter and fixed carbon. If this fuel-ratio were accidental, that is, subject to no known law, the method would fail to be of any general utility; but inasmuch as the fuel-ratios of both beds increase with remarkable uniformity from east to west, it is comparatively easy to make relative comparisons that are of actual value to the consumer. The tables plainly show the remarkable regularity in the increase in volatile matter and decrease in the fixed carbon of coal from both beds in going from east to west,—thus the extremes show:

| | Volatile matter. | Fixed carbon. |
|---|---|---|
| Clearfield County, Bed D, . . | 20.09 to 25.19 | 68.73 to 74.76 |
| do etc., Bed B, . . | 22.56 to 26.13 | 64.37 to 69.63 |
| Clarion County, Bed D, . . . | 37.15 to 40.80 | 51.39 to 56.36 |
| do Bed B, . . . | 35.70 to 42.55 | 47.51 to 55.44 |

Hence it appears that coal mined from both beds is of the same general character and therefore adapted to the same general uses in each district, varying principally in the percentage of impurities, but that all the coal mined in one district is unlike all that mined in the other.

The consumer, therefore, would probably be disappointed in the results of any comparisons made in this way between coals from different beds mined in widely separated districts, as for instance, the Clearfield D and the Clarion B; and it is not contemplated that the method should be applied in this way. In practice it can be applied safely only to coals from different beds in the same or adjacent dis-

tricts. Thus Clearfield, Centre, and Cambria County coals may be compared with each other; Clarion, Armstrong, and Butler County coals may be similarly compared, etc., etc. This rule has not been adhered to in preparing the averages of the different tables of analyses, and in the text also it is ignored, but the object of this paper is not to establish actual relative values so much as to show how these might be deduced by the consumer, and also to show the marked and persistent contrast between these two beds throughout the area to which the analyses apply, and the probability that similar marked differences might be found to exist between these and other beds in other mining districts.

It has already been intimated that the margin of difference in price between superior and inferior coals is rarely commensurate with their difference in quality, but there are many marked exceptions to this rule. Perhaps the most striking instance that can be quoted is that of anthracite- pea- and buckwheat-coal. Pea-coal varies greatly in ash. Some collieries produce a pea-coal with little more ash (slate) than the larger sizes; but in some cases the pea-coal carries a very large amount of slate and "bony" coal, the ash-percentage reaching or exceeding 20 per cent. For the purpose of illustration we may assume the average ash of pea coal at 14 per cent. and the average ash of the larger sizes at 8 per cent. With the large size quoted at $4.00 the pea-coal should then be worth at least $3.60, but the actual difference in price is much greater, and it would therefore seem clear that the smaller and inferior coal is the cheaper fuel at present quotations and that large consumers will effect a very considerable saving by purchasing it in preference to the larger sizes which are undoubtedly superior in quality but very much higher in price. This difference in the price of these coals has not arisen from any nice discrimination by the consumer, but from the difficulty (now overcome) in firing with small coal, and the excess of production over demand for these small sizes.

Here and there a consumer may be found using every available means to discriminate in the purchase of fuel; metallurgical works, ocean steamship lines, etc., may be mentioned in this category. The influence exerted by this class of consumers has been felt in some markets and has resulted in lower quotations for second- or third-grade coals. This is especially true of those markets supplied principally by Clearfield and Cumberland coal. Thus I have known of concessions from established quotations amounting to 25 cents per ton on Clearfield coal coming from a mine that had fallen into bad

repute, and this was more than sufficient to compensate for the difference in quality. It should be stated, however, that this particular instance occurred when coal at the mines was quoted at $1.25 per ton. Such concessions are no longer possible except by those operating in districts nearest market. The mines of McKean, Elk and Cameron counties may be so classed.

It may be of interest to inquire how much coal is mined from each of the two beds discussed in this paper within the limits covered by the analyses. In the absence of complete returns from each colliery it is impossible to give the exact figures, but the following summary, although only approximately correct, may be of use:

RELATIVE OUTPUT FROM THE DIFFERENT BEDS, 1884.

| | |
|---|---|
| Freeport Lower Coal (D), | 3,245,500 tons |
| Kittanning Lower Coal (B), | 1,140,500 " |
| Other beds, | 359,000 " |
| Total, | 4,745,000 tons. |

The area to which the conclusions of this paper apply may be indicated upon any map of Pennsylvania as follows: From a point ten miles southwest from the northeast corner of Cambria county, draw a line northeast along the Allegheny mountain to the Clinton county line, thence a north line to the New York State line. From the Cambria county point on the Allegheny mountain draw a line northwest through Brady's Bend on the Allegheny river to the Butler county line, thence north to the New York State line. In Potter, Cameron, McKean, Warren, Venango, and Forest counties, the Freeport Lower coal (D) is not found, and in Centre, Clinton, and Elk counties, its area is quite insignificant.

The Kittanning Lower coal (B) is not found in Potter, Warren, or Forest, and its area in Cameron and Venango counties is quite small. The mines of McKean, Potter, and Warren counties are opened principally upon the lower coals.

## DISCUSSION.

DR. J. P. KIMBALL, Bethlehem, Pa. (communication to the Secretary): Dr. Chance's reference to my paper on the Quemahoning coal-field of Somerset Co., is, I understand, particularly to the table of analyses on page 492 (*Transactions*, xii.). To this table, compiled from Report H (1875), of the Second Geol. Survey of Penn.,

were applied the revised nomenclature and notation of the later volumes of that survey. Since the reading of this paper, Report $H_7$ has been published, identifying the coal-bed of Moshannon Creek and the Morrisdale Branch R.R., not as the Kittanning Upper Coal-bed (C′) (new notation) *below* the Freeport limestone, but as the Freeport Lower Coal (D) *above* this limestone.

As in the paper referred to I followed the earlier volumes of the survey in point of identification of coal-seams, so am I bound to follow its later work. Thus specifying here what Dr. Chance alludes to in a general way, I improve the present opportunity to cite the newly discovered relations of the coal-bed in question, in accordance with the revised results of the work of the survey in Clearfield county, by way of amending the table referred to.

---

## *THE NEW MINING CODE OF MEXICO.*

BY RICHARD E. CHISM, M. E., SALTILLO, COAHUILA.

If internal commotion can be called life, the Mexicans have certainly lived more in the last seventy-five years than any other people. To the oppression of the Spanish viceroys succeeded the sanguinary tumults of the Revolution of Independence, after which the Supreme Congress bequeathed its heritage of uncertain power to the empire of Iturbide, the only one ever established by Americans upon American soil, with an American at its head. That short-lived reign was followed by years of ceaseless, bloody, and, to the superficial observer, meaningless revolutions—the deeper political and ecclesiastical significance of which it is beyond the scope of this paper to discuss. Then came foreign intervention, the ill-fated Austrian's brief supremacy, and the final triumph of the patriot cause under rugged old Benito Juarez, who crowned the victory of arms by a series of reforms breaking forever the temporal power of the Church and ushering in the calmer era which has lasted from the first accession of Diaz to the present day.

During all those troublous times, the revolutionary ocean, that rolled so deeply over all other relics of Spanish dominion, had left almost unaltered the ancient laws of Spain, still lifting themselves above the tide, like landmarks of a flooded world. Many of these laws were obsolete; some were absurdly inadequate to the demands

of modern commerce; and, above all, the cumbrous proceedings, which, deep-rooted in the ecclesiastical law, had overgrown the civil codes and customs, were smothering justice and throttling industry. These venerable abuses were not spared by the reforming hand of Juarez. A Civil Code was promulgated in 1870, and a Code of Civil Proceedings followed, which, with some later reforms, has reduced the costs and delays of lawsuits to a minimum. Then came a Penal Code, and a Code of Penal Proceedings. All these reforms were devised by competent experts, in the light of modern jurisprudence, and constituted important steps of real progress.

The establishment of Codes of Commerce and of Mining was delayed for some time, partly because it was thought unwise to reform too much at once, and partly because no express authority was conferred by the Mexican Constitution upon the National Government to control these matters. In view, however, of the vast increase of commercial operations, brought on by the building of railroads, and the reluctance of foreign capital to invest in mines under the antiquated *ordenanzas* of 1783, which were still in force, the States at length, in 1883, consented to an amendment to the Constitution by which the power of legislation upon mining and commerce was delegated to the Federal Government. Commissioners were appointed to form suitable codes, and in 1884 the Codes of Commerce and Mining were adopted as part of the laws of Mexico.

The old *ordenanzas*, now entirely superseded by the new Code of Mining, were established by the King of Spain in view of the pressing necessities of the industry, which up to that time had been only governed by customs, derived partly from the ancient Aztecs and partly from Roman law. An imperfect code had been promulgated in 1760, having been arranged in form of commentaries by one Señor Gamboa. It does not seem even to have had the full authority of a law, although it was consulted and deferred to in most points even by the courts. The *ordenanzas* of 1783 were founded principally upon the work of Gamboa, which continued to be consulted as an authority in the many cases in which the true intent of the law was obscure.

The process by which the *ordenanzas* of 1783 were formulated is worth detailing as a splendid instance of Spanish routine. We learn from the preface to them that the Viceroy of Mexico, in a letter of the 24th of December, 1771, made known to the King of Spain the urgency of a new law to reform the radical and hurtful abuses that

had crept into Mexican mining, and proposed the most efficacious means to do away with them. Having heard this and after an opinion from the Supreme Council of the Indies in June, 1773, and also various representatives from the same viceroy in 1774, and another meeting of Council in September, 1776, a commission was appointed January, 1778, which was ordered to frame the *ordenanzas* as soon as possible. Accordingly they were presented in August, 1779, and received the royal approbation in 1783.

The *ordenanzas*, as promulgated, established the mining industry into a formal body, like the Chambers of Commerce. They established, also, a Bank of Habilitation for the encouragement of mining, created a College of Metallurgy and gave directions for the acquirement and working of the mines, conferred various privileges upon miners, and set aside a portion of the royal revenue from the mines to support the above-mentioned establishments.

The supreme control of mining matters was committed, under the viceroy, to a Tribunal of Mining, with its seat in the city of Mexico. Mining Deputations were established in all mining centres.

The Deputations and the Central Tribunal decided all questions of an executive, administrative and economical nature, and had jurisdiction over discoveries, denouncements, claims, measurements, drainage, abandonment, bad working, and also over metallurgical works and water-rights.

Jurisdiction, as to questions of law and fact between individuals, was committed to the ordinary judges, who were to be guided by the prescriptions of the *ordenanzas* in all their decisions.

The real property of mines was established in the Crown of Spain, and concessions of the right to work them were made to individuals who acquired the property by discovery and denouncement, or by denouncement of an abandoned mine, and retained the ownership so acquired as long as they complied with the conditions of the *ordenanzas*, as to keeping up the work and working in a proper way. The principle of possession being dependent upon continuous work is said to have been handed down from the Aztecs.

On the establishment of Mexican independence only such changes were made in the mining laws as were necessary to adapt them to a republican and federal form of government. The Central Mining Tribunal was abolished and its functions devolved upon the Mining Deputations of each State. In some States the Mining Deputations were also abolished and the whole control of mining committed to the ordinary executive authorities and the ordinary courts. The

prescriptions of the *ordenanzas* relative to the mode of denouncing and working the mines continued in force, with scarcely any modification, although the interdependence of the various parts of the *ordenanzas* created great confusion in the application of those parts still in vigor. Some minor changes were made later on by the legislatures of several States, and two or three States even established formal codes of their own for the regulation of mining. There was also a diversity of practice in the several States relative to the taxes to be imposed on mining capital and on metallurgical works, and in some States the industry was seriously crippled by the onerous burdens laid upon it by injudicious legislation. This state of affairs as a whole was highly detrimental to the mining interest, and hence the new Code of Mining was designed, like its predecessor, to correct the abuses which had crept into Mexican mining. We shall best see, by discussing it, chapter by chapter, in what respects it differs from the old code; and I shall leave it to others to judge how far these differences are likely to be beneficial or the reverse.

## I.

Chapter or Title I. of the new Code treats of mines and mining property. The Code is declared to apply to mines and deposits of all those inorganic substances which, in veins, beds, or masses of any form, constitute deposits whose composition is distinct from that of the country-rock; to placers of gold and platinum, with their accompanying metals, and of the precious stones. It also applies to metallurgical works of all kinds, and to sites where they can be constructed, to the waters extracted from the mines, and to those necessary for the drinking of workmen and animals, for motive power, or for any other use in metallurgical works.

The property of the above enumerated deposits is defined as forming a realty, distinct from the soil or ground in which, or upon which, they are found, even if they should belong to the same owner. These properties are to be acquired, originally, by denouncement and concession by the proper authorities, and subsist for an unlimited time under condition of working according to the precepts of the Code, and the regulations to be dictated in accordance therewith. Mining property can be acquired and held by foreigners on the same terms, and subject to the same restrictions, with which they may hold other real estate in the Republic of Mexico.

The owner of the soil has exclusive property in deposits of all kinds of mineral coal, in the rocks in place, and the materials of the

soil, such as limestones, slates, porphyries, basalts, building-stone, earths, clays, sands, and in other analogous substances; also, in placers of iron and tin, or other bulky minerals; in the salts which exist in the surface, and in fresh or salt springs, superficial or subterranean; in petroleum and gas springs, and in thermal and medicinal waters.

In the exploitation of the above, the owner must be governed by regulations of police, and in the working of coal will be subject to the Mining Code, so far as it relates to the proper working of the mines and the security of the miners.

The same title also allows the work of exploration to be undertaken, and mining property to be acquired in any lands, whether of public or private property; but, in the latter case, the owner of the soil must be indemnified for that portion of the surface which the miner may occupy or over which he may have to pass.

As will be seen, the mining property in Mexico is still held, as in the old ordinances, separate from the ownership of the soil. We have, however, a clearer definition of what mining property is, than in the old law, and a complete departure from its principles in respect to the ownership of coal mines. The property of coal mines, in the State of Coahuila, was granted to the owner of the soil by a decree of the legislature of the State in 1882, and this principle has been adopted in the new Code. It has caused a great deal of dissatisfaction in Mexico, and may, perhaps, be repealed.

In respect to the ownership of mining property in Mexico by foreigners, we have them put upon the same footing as they are with respect to other property. According to the Constitution of Mexico, foreigners are to have the same protection and guarantees as natives, with only the obligation to contribute to the public expenses in the manner prescribed by law, and to respect the institutions, laws, and authorities of the country. The government has, however, a right to expel any pernicious foreigner. This Constitution was established in February, 1857. There had been, however, a law passed in August, 1824, by which foreigners were prohibited from acquiring lands situated within a zone of twenty leagues along the line which divides the republic from neighboring nations. To acquire such property special permission must be had from the central government. This law was, in substance, re-enacted in 1854 and 1856; and, although there are some doubts as to its constitutionality in view of the articles of the Constitution quoted above, still it has never been repealed, and is in force to-day. It was, not long ago,

made the pretext for nullifying the sales of a portion of the State lands of the State of Coahuila to an American Company or syndicate, and it would undoubtedly be held, under the provisions of this title of the present Code, to vitiate the title of foreigners to mining property within the above limits. There is an old law in Mexico, said to be of Spanish origin, which provides that any foreigner who may remain more than two years out of the republic shall forfeit to the nation any real estate of which he may be possessed. But there is a special clause of Title I. of the present Code which exempts mining property from the operations of the law just mentioned. Besides the above, I know of no restrictions upon the holding of real estate in Mexico by foreigners.

## II.

The second Title of the Code treats of the authorities who are to deal with and take cognizance of mining matters. According to this chapter, the mining industry, so far as relates to administrative and economical questions, is to be dependent upon the Ministry of *Fomento*,* and the functionaries made subordinate to that ministry by the present Code. The decision of disputes between individuals is left, as in the old law, to the ordinary judges and tribunals.

This Chapter goes on to establish in the city of Mexico a corps of engineers and miners, subordinate to the Ministry of Encouragement, which is to be composed of three graduated experts and three mine-owners, and which is to be a consulting council for the encouragement of mining. It is to deal with all scientific, economical, and administrative problems that may be submitted to it by the Ministry of Encouragement; and it is to promote, in a general way, the improvement and advancement of mining. Mining Deputations, established in any mineral district where the Ministry of Encouragement may deem it necessary, are to exercise all the administrative and economical functions marked out for them by the Code.

From other articles of the Code, and its accompanying regulations, we learn that these functions are the registration of denouncements and the proceedings in connection therewith, the giving of possession of mines, granting licenses to explore for new mines, examination of mines from time to time to see if they are being worked

* This ministry corresponds to our Department of the Interior. If we translate *Fomento* by "Encouragement," which is its nearest English equivalent, the full title of the office will be, "Ministry of Encouragement, Colonization, Industry, and Commerce."

conformably with the Code, the collection of mining statistics, the supervision of new works of importance, such as drainage-tunnels, etc. In the absence, at any place, of a mining deputation, its functions are to devolve upon the highest executive authority of the place. Title II. goes on to prescribe that, in important mining districts, there shall be a graduated expert attached to each deputation as its official adviser, and also that the Secretary of Encouragement may nominate as many mining engineers as may be necessary, inspectors to visit the mineral districts, and to make reports of their studies and examinations for the information of the bureau.

## III.

Title III. treats of explorations for the discovery of mines, and declares that every inhabitant of the Republic, native or foreigner, shall have the free right to explore for minerals in public lands with excavations which must not be over five meters in depth or diameter, except when made by boring-machines, in which case they may be of any depth. In case the ground should be private property, and opposition to prospecting should be made, on the part of the owners, application must be made to the head executive authority of the place, who can grant permission to explore under certain restrictions. If the land in which the prospecting is to be done is neither fenced nor cultivated, the authority shall issue the permit to explore on the explorer's giving a sufficient bond to be responsible for the damages which the explorations might cause to the owner of the property. In case the land is fenced or cultivated, the authority shall hear the interested parties, and shall appoint an expert to report upon the necessity of the exploration and the damages that may be caused thereby, and the permit may be granted or denied, as the authority may deem proper. In any case, the explorer must give his bond, within ten days, for the estimated damages, without which bond the permit cannot be issued. The permit must clearly express the place or places where the exploration is to be made, the number of men to be employed therein, and is always to be understood to be granted on condition that the time to be employed in searching for minerals is not to be more than one month, which, for well-founded reasons, can be extended, after a new application, to two months, and that the depth and diameter of the excavations is not to exceed five meters, except when boring-machines are used. During the time necessary for obtaining the permit, during the time which the

latter is to run and for one month after, neither the owner of the land, nor any person except the prospector, can denounce a mine of any substance whatever, either in the place designated for the search or within a distance of 300 meters from the same in all directions. The prospector loses his exclusive right to denounce, if he does not do so within one month after the expiration of his permit to explore.

The consent of the owner is indispensable to enable prospecting to be done within any house or edifice or its dependencies, or within a distance of thirty meters from the walls of such property, and no prospecting will be permitted in the streets or public places of a town nor within thirty meters from the exterior lines of roads or canals, archways, aqueducts, dams, bridges, etc.

The prescriptions just recited are certainly no more than equitable in view of the progressive settlement of Mexico. There is, however, every reason to fear that they will, in many cases, prove a hindrance to prospectors, and be used for purposes of blackmail. The provision as to the depth and diameter of prospect-holes, is plainly one of those laws that are made to be broken. No prospector will limit himself to such dimensions, if he thinks there is anything to be gained by going further, especially as there is no penalty attached to non-observance of the law.

## IV.

The fourth Title of the Code treats of the mode of acquiring mines, placers, abandoned metallurgical works, or sites to establish works, and of the waters to be used for water-power in metallurgical establishments and mines. The title to the above is to be originally acquired by judicial award made in virtue of a denouncement. A denouncement may be made as of a discovery, on account of abandonment, or for forfeiture or extinction of the title of a former owner for non-obedience to the precepts of the present law in those cases which it expressly determines. A discovery may be of a new mineral district, of a new deposit in a known district, or of a new mine in a known deposit.

The discoverer of a new mineral district, or the restorer of an abandoned district in which no work has been done on any of the mines for one year, is to have a right to three consecutive claims on the principal vein or deposit and to one more on each one of the other veins of the same district. If the discovery or denouncement should be made by a company, constituted according to the present

code, it shall have a right to four consecutive claims with the measurements as fixed in Title V. of the Code.

A mine is to be considered deserted and abandoned, and may be adjudicated to any one who denounces it, after a cessation of work for twenty-six weeks, consecutive or interrupted, during the year previous to the denouncement.* In case of disturbances of the public order, or of other great calamities within twenty leagues of the mines, the work can be suspended on them, and they shall not be open to denouncement for desertion until tranquility has been restored, and a proclamation to that effect made by the Mining Deputation of the place, when the owners are to have four months' time to commence work.

A license to suspend work on any mine for more than twenty-six weeks may be obtained for good and sufficient cause from the Mining Deputation of the place, which may grant such a license for six months only.

An especial permit to cease work for a period of more than six months and not to exceed one year can be obtained, after good cause shown, from the Ministry of Encouragement. In no case can these permits be prolonged beyond the time once granted, and no second permit to cease work can be extended to the same mine within a period of three years. A permit to cease work may also be granted by the Mining Deputation for the purpose of enabling a mine to be held during the accomplishment of works in other neighboring mines, which are to facilitate the exploitation of the one in question.

A mine may be denounced as badly worked when the life of the workmen is in danger on account of the workings being in a ruinous or insecure condition, or when the workings are so badly ventilated that the lights refuse to burn, and the health of the workmen is in danger, or when the necessary drainage of the mine has been stopped for twenty-six weeks during the year preceding the denouncement.

In case of a denouncement for the preceding reasons, the Mining Deputation is to have the mine examined by an expert, and, if any of the above defects are found to exist, the owner is to have a term of six months, in which to correct them. If the owner should fail to do so, the mine is to be awarded to the denouncer, provided the latter shall give a bond for the costs of changing the defective portions of the mine or of reestablishing the drainage.

---

* This is a considerable change from the old *Ordinances*, which allowed a suspension of only four months.

The rest of Title IV. is devoted to laying down the proceedings to be followed in cases of denouncement for discovery or abandonment. The most important parts of these are that the denouncement is to be published during three weeks in the official newspaper of the district or State; also, the former owners of an abandoned mine are to be cited if known. If the denouncement is of a vein, the denouncer must open a shaft and gallery on one of the walls. These workings are to have a section of one and one-half meters of side or diameter, and to be five meters deep and long. In a mass-deposit equivalent excavations must be made in two different directions sufficient to give an idea of the nature and geological formation of the deposit. The administrators, dependents, or workmen of any mine are prohibited from making denouncements within eight hundred meters thereof, and no denouncements can be presented to take effect in case a former one should be disallowed. In case of dispute between discoverers, the first registry is to prevail, and the right of any denouncer is to be forfeited in case he does not do the necessary work, as above described, within four months from the date of his denouncement, or within such additional time, not to exceed two months, as may be granted by the Mining Deputation.

A metallurgical work is held to be abandoned when the roofs, machinery, tools and timbers are entirely gone, even if the walls, etc, should be standing; or, if no work has been done therein during three years, and if the owner, on being notified by the Mining Deputation, does not reëstablish the works in a term not to exceed six months. In case of denouncement of a metallurgical works or mine, the former owner may claim, and must be paid the value of any serviceable sheds, machines, etc., which he may have left there.

Any unused current or fall of water may be denounced to be employed in a mine or metallurgical works for motive power, or for working the ores, and the denouncement shall pass through the same proceedings as those of mines.

Any water-right not used for a period of twenty-six weeks, may be denounced as abandoned.

The waste-piles and dumps of mines are not denounceable except by denouncing, at the same time, the mines to which they belong; the slag, piles and slime-pits of metallurgical works can also only be denounced with the works themselves.

The miner who needs to occupy any part of the surface of the ground to open mine-entrances, or to establish roads, workshops,

dams, aqueducts, or for the purpose of utilizing the superficial part of any deposit, must pay the value of the ground, leaving that of the mineral out of consideration. This valuation is to be made by experts, one named by each party, and a third by the Mining Deputation.

## V.

Title V. treats of the dimensions of mining claims. The claim, or unit of measurement for mineral concessions, is to be a solid of indefinite profundity, limited on the exterior by the projection on the surface of the earth of a horizontal square or rectangle, and under the surface by four vertical planes passing through its respective sides. The dimensions of the square or rectangle are fixed according to the nature and position of the deposit, so that the miner may exploit and utilize all the mineral substances which exist in the interior of his claim and also those which exist on the surface after indemnity to the owner of the land for the part of the surface occupied. A mining concession of whatever number of claims it may consist, is indivisible.* Proceeding to fix the size of the claim, the code prescribes that the sides parallel to the strike of the vein shall be 200 meters long, measured horizontally, and the length of the other two shall vary between 100 meters for a vein of 85° or more of dip, to 300 meters for a vein of 45½ degrees or less. The object of this is declared to be that the miner may, as a general rule, exploit 400 meters upon the vein in the direction of its dip.

For concessions of placers of gold, platinum, and precious stones, the upper face of the claim is to be a square of 20 meters on each side, measured horizontally. In concessions on blanket veins or on irregular deposits the upper face of a claim is to be a square of 300 meters on each side. If the deposit should be of iron the upper face of the claim is to be a square of 500 meters on a side.

In laying out a claim, the denouncement-working made according to the provisions of Title IV. must be comprehended within the limit of the claim, and whatever may be the irregularities of the ground no fractional claim can be measured off. No claim can be laid out on ground already occupied by a mining possessor. That is, no claim can overlap another; and where a concession is composed of several claims, they must be measured consecutively, so that each concession shall be contained within a single rectangle, even if it should be necessary to reduce the number of claims which ought to go to each miner, in order to comply with this requisite.

* That is, it cannot be sold off in portions, as in feet along the vein, etc.

If any miner shall observe, after taking possession of his claim, that the vein has undergone a change of strike or dip, and should wish to alter his claim to correspond, the Mining Deputation may permit this, within the term of one year after the taking of possession, provided no prejudice can result therefrom to third parties.

Any vacant piece of ground between two claims, not large enough for another claim, shall be divided between the adjacent claims, or, if one of the adjacent owners has already entered upon such vacant ground with workings not less than 100 meters long or deep, it shall be awarded to him as a whole.

Any mine owner may prolong his workings into vacant ground adjacent to his claim, and may then acquire that ground by denouncement, to an extent not more than equal to his original concession.

A miner may enter upon an adjacent claim for the necessities of ventilation or drainage, by permission of the Mining Deputation, or may follow ore into such a claim. In any case he is obliged to divide equally, the ore taken out of a strange claim, with the owner thereof, who must pay one-half the cost of getting out the same. This arrangement is to subsist only until the owner of the invaded claim makes an underground communication with the invading workings, after which each party is to keep to his own property, and a grating is to be fixed on the dividing line.*

## VI.

Title VI. of the new Code prescribes the manner of working the mines. They are to be exploited according to the rules of the art, and in conformity with the provisions of this title and with the police regulations which may be adopted. The principal conditions are that the necessary ventilation is to be maintained in the workings by either natural or artificial means; that the interior passages must be of ample width, and that at least two passage-ways must be made to the exterior in all mines employing more than fifty workmen. All weak places are to be sustained by timber or by masonry,

* The provisions of Title V. are no innovation upon the old law except that the geometrical principles defining the volume of a claim are a little more clearly expressed. The size of the claim on veins is also considerably augmented. The old law gave the claim a length of 200 *varas* by a width of from 100 to 200 *varas*. This was equal to a length of 167 6 meters by from 83.8 meters to 167.6 meters, whereas the claim is now to be 200 meters long by from 100 to 300 meters in width.

wherever necessary, to avoid any sliding or caving in, as are also the stopes and places from which the ore has been removed. The workings and roads are to be kept free from rubbish, which is to be used to fill up in the mine, or dumped outside in places where it will not obstruct the streams. The necessary drainage of a mine is to be kept up without interruption.

The fulfilment of these conditions will be watched over by the Mining Deputations and other agents of the authorities. The Mining Deputations are to visit the mines in their district at least once in two years, and if any infractions of the Code are noticed, the owner must correct them, on being so ordered by the Deputation. The penalty for disobedience to this order is a fine of from 50 to 250 dollars for the first offence, and double this quantity for the second offence, in which case the Deputation may order the total or partial suspension of the workings of the mine until the evil has been corrected. In case any complaint by outside parties, as to the infraction of the Code, is found to be justified, the Mining Deputation may order the suspension of all or a part of the work of the mine in question as a precautionary measure, until the proper changes have been made. If this suspension should last more than six months, the mine may be denounced as abandoned.

The direction of the internal and external workings of a mine, the beneficiating of ores, and the establishment and care of machinery, shall be confided to scientific or practical experts of known ability. If this is not the case, the mine-owner shall be responsible for any accidents that may occur from unskilfulness in a mine or from mining machinery.

The Mining Deputation must take care, in any mine not usually directed by a graduated expert, that the services of such a person shall be had for the laying out of important workings such as tunnels, general shafts, galleries of communication, etc., and that such works shall be inspected by such an expert at least once a month.

A graduated expert must also be called to superintend galleries which are to communicate with flooded workings or with those that contain mephitic gases, and the execution of workings which might affect the security of the edifices or inhabitants of the surface.

The administrators of mines must inform the Mining Deputation of any accident to workmen occurring in the interior of the mine, and also of any sliding down, caving in, or flooding that may take place. In every mining enterprise employing more than two hundred

workmen, there must be a stock of medicines and a surgeon who can render the necessary assistance in cases of accidents to the workmen.

## VII.

Title VII. of the Code treats of the drainage of mines, of adventurer-tunnels, and of galleries for general exploration. The drainage of mines must be continually maintained, so that if any mine-owner works only the upper portions of his mine, without keeping up the drainage of the lower ones, his mine may be denounced. Mine-owners, whose mines are wholly or partially drained by the drainage of neighboring mines, must contribute to the cost of drainage in proportion to the benefit they may receive. This contribution is, however, in default of agreement between the mine-owners, limited to the tenth part of the product of the mine below the water-level, as fixed by experts. This is the recompense for the total drainage of the mines, and is to be diminished in proportion as the benefit received may be less.

If it seems apparent that a tunnel would facilitate the drainage, exploration, or working of several mines in any class of deposits, the owners of the mines or outside parties may undertake the same, if the work is possible and useful in the judgment of an expert named by the Mining Deputation. The denouncement for the tunnel must be made in due form, and is to be accompanied by a plan showing the proposed course and length of the tunnel, the mining claims through which it must pass, and those within one hundred meters on either side of the line.

When a tunnel is to be opened following a vein, the width of the claim shall be that which corresponds to the dip of the vein according to Title V. (*i. e.*, from 100 to 300 metres), and the length of the claim shall be that of the projected tunnel. If the greater part of the tunnel should be outside of a vein, the width of the claim shall be 100 metres, laid off equally on each side of the projected lines, and the length of the claim shall be that of the tunnel itself. In any ground where mining possessions already exist, the vacant portions between them may be conceded to the tunnel-owner, and his measurements may cross other mining claims, the property in which he is, however, obliged to respect.

The tunnel-owner must comply with the provisions of this Code, and with any special regulations which the Mining Deputation may make in the case. He may open his tunnel not only through vacant ground, but also through mining claims of other owners, and he may

denounce and acquire as many as five new or abandoned mines, with four claims to each one, provided they are within 150 meters from the line of the tunnel. He may also acquire three claims upon each new vein or deposit he may encounter in opening the tunnel. All these mines are to be considered as annexed to the tunnel, and their ownership is preserved to the tunnel-owner as long as work on the tunnel lasts. When this is completed each concession must be worked separately.

Any ores met with in opening the tunnel through strange ground must be equally divided with the owner of the ground, who must also pay one-half the cost of extraction.

If the tunnel has been opened to drain certain mines, and if no other agreement has been made, the tunnel-owner shall receive ten per cent. of the product of the mine from the part so drained. Any mines that use the tunnel for transportation and extraction, must pay five per cent. of all ores they take out through the tunnel. No tunnel-owner or any other miner in general, can claim remuneration for having ventilated other mines by means of their workings.

General working or drainage-shafts, provided with adequate machinery, and the galleries that lead from them, are to have the same privileges as adventurer-tunnels.

Permission may be granted by the Mining Deputation, under proper conditions, to open, even in outside claims, any gallery of exploration or other working likely to be useful for the exploitation of several mines.

## VIII.

Title VIII. treats of Mining Companies. These are to be governed by the prescriptions of the Civil Code of the Federal District of Mexico, in all cases not specified in the present Code. No mine can be divided up between several owners; hence no partners of a mining company can claim to work any particular part of a mine for their own individual account. All work must be done in common, and the expenses and products shall be divided according to agreement, or in default of this, in proportion to the stock of each partner.

All mining companies must be formed under a recorded agreement as an essential requisite. This agreement must contain the name and domicile of each of the partners, and show the stock which each partner represents in the company. Without these requisites, the company will not be held as constituted.

In every mining company the mine shall be considered divided into a certain number of shares, and each partner shall have a right to one or more of these according to agreement. Any partner may convey away his part without giving his partners preference over an outsider for the same price, but unless the stock is made out to bearer, he must notify the director or administrator of the company of the name of the party to whom he sold. The death of a partner does not dissolve a mining company; the rights and obligations of the deceased descend to his heirs.

It is not necessary that the capital of a mining company be fixed and determined; the shareholders are only responsible up to the value of their stock, less the amount they have actually paid in toward working the mine. If no value has been set upon the shares at the time of forming the company, the stockholders shall not be responsible for the debts of the company beyond the value of the mine or business, including everything belonging thereto.

Shares in a mining or metallurgical company are personal property, and must be represented by shares to bearer or to order, and transferable by endorsement.

Unless otherwise stipulated in the original agreement, all points arising with relation to the exploitation, administration, etc., shall be decided by the majority of votes, but to pass any resolution which implies the conveying away of the property in the mine, the votes must be unanimous.

In all such deliberations, the owner or owners of one share shall have one vote, and the owner of several shares shall have one vote for each; but if any one person should be the owner of half, or more than half, of the stock, his vote shall count for one less than the half of all the votes.

In any case where there is no decision on account of equality of votes, the Mining Deputation shall decide the matter, in view of what was brought forward during the meeting of the company and taking into account equity between the shareholders and the interests of mining.

All meetings of mining companies must be called at least fifteen days in advance. The summons must be delivered in person or by agent to all known stockholders and must express the object of the meeting; unknown stockholders shall be summoned through the newspapers.

Any shareholder who does not pay his part of the expenses or his assessment, within two months, shall lose his shares, which shall

revert to the other shareholders. Before this can be done, however, the Mining Deputation must be notified of the date when the shareholder became delinquent, and, unless service of the notice to pay assessment is proven, he must be notified in person or through the newspapers for at least fifteen days.

A shareholder whose stock may be declared abandoned may appeal to the courts within fifteen days after being notified thereof; after fifteen days he shall have no remedy. He will always, unless there is an agreement to the contrary, preserve a right to be repaid all he has paid in toward working the mine out of fifty per cent. of the clear profits of the mine, first deducting the expenses paid by the other shareholders before and after his shares were declared abandoned.

Any or all of the provisions of the law relative to mining companies may be annulled or waived by the contract or statutes of the Company, except those relating to the indivisibility of a mining property, to the recording of the original agreement of the Company with the names and representation of the stockholders, to the division of the mine into shares of stock, to the indissolubility of a company through the death of one of its members, and to the shares of mining companies being personal property.

## IX.

Title IX. treats of contracts of habilitation and other contracts with reference to mines.

The contract of habilitation, or to furnish necessary moneys to the mine owner for working his mines, may be made by the habilitator becoming part-owner in the mine or as a simple loan or assistance. In either case the stipulations of the contract between the parties are to be observed or, if no contract exists, the provisions of the law.

When the agreement is that the habilitator acquires a part of the mine he shall keep his part as long as he maintains the habilitation; the profits shall first go to pay off the habilitation-debt and afterwards be divided between the owner and habilitator according to the part of the mine each one represents. If the habilitator should cease to habilitate he shall lose that part of the mine which he has conditionally acquired, but shall have a right to be repaid all the capital spent on the mine.

The mine-owner cannot be held with his other property to pay capital advanced for working mines; such debts are to be paid from the profits of the mine, of which fifty per cent. is to be used in pay-

ing off the habilitation-debts; that of shortest standing is to be paid first, and so on.

The debts, incumbrances or mortgages which a mine may have are extinguished in case of losing the property on account of abandonment or for non-observance of the precepts of the Code.

Habilitation-debts can be secured by mortgage on other property, distinct from the mine; they are preferred over all other debts against the mine except workmen's wages. Among several habilitators the preference shall be given to the last. These rules shall take effect even when the mine and business are attached and sold judicially.

If a habilitator agrees to furnish a certain amount of capital or to habilitate for a certain time, he must carry out the agreement under penalty of losing the right to collect whatever he may have paid in; and the miner may bring suit against him to compel fulfilment. A miner to whom the habilitator does not advance in time money to pay the workmen, may sell any available effects or tools to raise the necessary funds and any loss thereon shall be for account of the habilitator.

Every habilitator who does not administer the mine may put in an inspector for his account and the mine-owner may do the same when the habilitator administers. These inspectors shall not interfere with the administration of the mine, but shall watch and examine the operations, books and accounts and give notice to their employer of whatever he ought to know.

In sales and contracts with respect to mines or shares therein, there shall be no rescission on account of wrong, nor resource of integral restitution.*

Mine-owners and workmen are free to contract with each other to work mines on shares, or for salaries, or in any other way, and the contracts relative thereto shall be governed by the provisions of the common law.

## X.

Title X. treats of legal proceedings in mining lawsuits. The Mining Deputations must subject themselves in all economical and

* The action for rescission on account of wrong holds where the party who buys anything pays twice its value, or where the seller of anything receives only one-third its value. The resource of integral restitution holds in behalf of a minor for the return of a property wrongfully sold by a trustee or guardian, when the goods of the guardian are not sufficient to indemnify the wronged party, or for the rescission of sales made by a minor under tutelage with the consent of the tutor, if loss has resulted to the minor thereby.

executive proceedings to the provisions of Title IV. and VI. of this code.

Mining lawsuits must be substantiated and decided in each State by the proper judges and tribunals of that part and according to the laws of proceedings there in force, but with observance of the rules contained in this title.

The proceedings shall be summary whenever by its own nature the suit has not an especial or a short form according to the local laws in force.

The work of a mine or metallurgical works cannot be suspended on account of litigation, or attachment; an inspector can only be put in. The machinery, tools, utensils and provisions necessary for or on hand in a mine or metallurgical works cannot be attached or sequestered separately from the business for any debt of the mine-owner except that, for the pay of the workmen, there may be taken and sold of the above objects enough to cover the debt. In every case of sequestration or execution of a mine or metallurgical works the products thereof shall be devoted first and of preference, to keeping up the workings.

## XI.

Title XI. treats of taxes upon mining. During the term of fifty years, counting from January 1st, 1885, the date of this law, all mines of mineral coal, iron and quicksilver, are to be exempted from direct taxes of every kind. Mining products are to be free from all taxes on their circulation within the Republic, and quicksilver is to be free from all customs dues and all direct taxes.

Besides the coinage and exportation duties now levied, or that may be established, the mines, not of the class especially excepted as above, are not to pay more than one direct tax, which is to be fixed according to the value of the ore or substance in exploitation without deduction of expenses, and which shall not exceed two per cent. of said value. This tax is to go to the State in which the mine may be situated, or to the Federation, if the mine should be in the Federal District or the Territory of Lower California.

Metallurgical establishments shall pay the same taxes as other industrial establishments.

## XII.

Title XII. contains general provisions. It lays upon the Mining Deputations the obligation to watch over the exact fulfilment of this present law under direction of the Ministry of Encouragement. Where there is not time to communicate with that functionary, the

Deputations may, on their own responsibility, take such urgent measures as may be necessary for the preservation and regulation of the work in mines and the executive authorities must lend them all necessary assistance thereto.

The Mining Deputations and their employees shall be responsible for official misdemeanors or abuses, according to the Penal Code of the Federal District. They and the experts, etc., shall be paid by fees according to the schedule formed by the Secretary of Encouragement, which fees are always to be paid by the denouncer or promoter of any proceeding or question.

Proprietors or habilitators of mines must have an agent or attorney in the district where their mines are seated, duly authorized for all legal proceedings. In default of such agent, any proceedings may be taken against the administrator or person in charge of the mines, without any necessity of notifying the mine-owner.

Owners of mines or metallurgical works are obliged to supply such statistical data as may be asked for by the Mining Deputations, according to the instructions of the Secretary of Encouragement or of the General Directory of Statistics.

All mining properties legally acquired before the date at which this law commences to be in force, are to continue to be held even if of deposits or substances not comprehended in this law, or if their claims should have dimensions different from those now established. If such properties should be of substances which the present law awards to the owners of the soil, those at present in possession thereof by virtue of denouncement shall continue to hold the same and shall enjoy an especial protection from denouncement for two years from the date of this code, in order to arrange for putting their properties in exploitation. After this time if such properties are abandoned or forfeited, all rights therein shall revert to the owners of the soil.

Those States whose taxes upon mining and metallurgical works of any kind are not in conformity with the provisions of this code are to pass the necessary legislation to make them so before July 1st, 1885.

This Code, dated November 22, 1884, took effect all over the Republic from and after the 1st day of January, 1885, at which time the Mining Ordinances of May 22, 1783, and all laws, decrees and regulations of the colonial epoch, of the Federation or of the States, concerning the industry of mining, were absolutely abolished, even in those parts not contrary to this Code. The digest above given contains all the main points of the new law. For the minor provisions and for the detailed proceedings under the Code I must refer to a complete translation which I expect to publish in another place.

## *THE IRON ORES OF PICTOU COUNTY, NOVA SCOTIA.*

BY E. GILPIN, JR., A.M., F.G.S., F.R.S.C., INSPECTOR OF MINES, HALIFAX, N. S.

THE following notes may serve to bring before your Institute an idea of the iron-ore resources of Pictou County. Enough work has been done to permit an estimate to be formed of their quality and probable extent. As yet the systematic mining and smelting of iron-ore in Nova Scotia is confined to the operations of the Steel Company of Canada, in Colchester County.

Although the locality I am about to describe appears, in many respects, well adapted to iron smelting, etc., no attempts have yet been made to begin work. Nova Scotian capital is more readily turned to lumbering, fishing, and shipping ventures; and such an investment appears equally foreign to the rest of the Dominion. I need not, however, go further into this part of the subject, and can only hope that my notes may prove serviceable as indicating a probable field for future development.

The accompanying map shows the position of the harbor of Pictou relative to the coal and iron-ore fields, and to the railways which intersect them. The branch of the Intercolonial Railway, running from Truro to Pictou, forms the western boundary of the iron-ore district, which extends beyond the point where the New Glasgow and Cape Breton Railway crosses the French River. The iron-ore district may be roughly described as a triangle formed by the ore-outcrops and the two railways, the former making the base, and the latter the sides of the triangle, the apex resting on the coal-field at New Glasgow.

The drainage of the country is toward the Gulf of St. Lawrence, through the Middle, East, Sutherland's, and French rivers; and the surface is undulatory, seldom exceeding two hundred feet above the sea-level, except in the district lying between Glengarry and the upper waters of the French and Sutherland's rivers, where a maximum height of about five hundred feet is reached at several points.

Geologically speaking, the district embraces two divisions, the Carboniferous and the Silurian, the latter resting on strata provisionally considered to be of pre-Cambrian age. As no geological

survey has yet been made of this county, except in the coal-field, the boundary lines of the various horizons cannot be indicated with absolute accuracy.

From New Glasgow northward to Pictou are met the measures of the Upper Carboniferous (embracing the upper part of the productive measures). These strata are considered by geologists to mark the transition from the Carboniferous into the Permian, and the term Permo-Carboniferous has been applied to them. The town of New Glasgow lies on the northern outcrop of the coal-measures, which extend from Sutherland's River to Middle River, and are bounded by heavy faults, bringing the different Carboniferous subdivisions into close contact with each other. The Millstone-Grit occupies an irregular tract of country lying to the south of the coal-field. The sections which have come under my notice do not show any clearly defined boundary to this formation, which appears to pass insensibly into the coal-measures above and the Marine limestone beneath.

The latter formation, which is of interest in this connection, as it holds numerous beds of limestone, iron-ores, etc., is presented in an irregular band, extending from Glengarry to Sutherland's River, and projecting to the south up the East River in a narrow tongue. The lowest division of the Carboniferous, represented elsewhere in the Province by dark-colored bituminous shales or by heavy beds of conglomerate, does not appear in this district.

The various members of the Carboniferous system rest on two divisions of the Silurian. The upper division has for its western boundary the East River, and occupies the highlands, already referred to, as extending from that point to the eastward. The beds making up this series are gray and olive slates, in places passing into coarse grits and sandstones, and containing a few calcareous bands. The fossils they yield are considered by Dr. J. W. Dawson to be the equivalents of those characterizing the Lower Helderberg of United States geologists. Passing downwards, underlying strata are met, which, in the absence of the Niagara limestone may be regarded as of Clinton age. These ferriferous strata are now presented in synclinal folds, irregular in shape, and frequently broken by faults, and rest on nacreous and chloritic schists with immense masses of an indurated slaty breccia, rising into prominent hills.

On the west side of the east branch of the East River the Carboniferous rests on strata, composed largely of black and gray slates and quartzites, older than any met on the east side of the river,

except possibly the hills of indurated breccia. At several points patches of strata, perhaps representing the lower beds exposed on the east side of the river, intervene between the Carboniferous and the older strata. These slates and quartzites are considered to be the eastward extension of the axial measures of the Cobequid Mountains, which they strongly resemble, and have been termed Siluro-Cambrian. As yet, however, the work of mapping out these horizons has been incidental to the exploratory work on the various iron-ore deposits, and much remains to be done.

Although the presence of a few of the iron-ore beds about to be described had been known for many years, no attempts were made to prove their value until 1873. In this year Dr. Dawson, assisted by his son Mr. George Dawson, determined the position and extent of some of the more important deposits, and their work was continued by the writer for several seasons over a district embracing three hundred square miles.

Taking the ores in ascending geological order, they occur as follows:

| | | |
|---|---|---|
| Cambro-Silurian. | | Specular magnetite. |
| Upper Silurian. | | Red hematite. |
| Carboniferous | Marine limestone. | Spathic ore. Red hematite. |
| | Millstone grit. | Nodular clay ironstone. |
| | Coal measures. | Clay-ironstone. Blackband. |
| | Upper coal measures. | Clay-ironstone. |
| Recent. | | Bog-ore. |

The iron-ore district of the Cambro-Silurian series begins about six miles to the northwest of Glengarry station, where there are several veins of specular ore in Gairlock. These veins, as exposed naturally near the farm of James McKay, of Mill Brook, vary in thickness up to 2 feet, but no work has been done to test their extent. About two miles west of Glengarry a large vein crosses the railway, and is composed chiefly of ankerite with sideroplesite, and a little calcspar, and carries several veins of specular ore. One of these has been opened by a short drift and shows 3 feet of excellent ore.

From this point eastward to Drug Brook on the west branch of the East River traces of specular ore are frequently met, but no veins have been observed. Here a natural exposure shows three beds of limonite, the thickest being about 30 inches in width. It is not known with certainty that these ores represent the specular already referred to, and they have been considered to belong to a second ore-range, lying to the south of the specular. From this

point, surface-signs of specular ore mark the passage of the vein for about three miles, to an opening made by Mr. Watson on a vein of specular ore 7 feet wide. A few yards from this is a bed of a dark-colored magnetic ore, about 18 inches wide; but no details are known as to its extent and value.

The specular vein has been traced about four miles further to the east, and shafts have been sunk on it at several points. On the Weaver property, enough work has been done to show that the vein is about 100 feet wide, and carries several bodies of specular ore from 1 to 15 feet thick. About one-half a mile east of the Weaver property, where the vein begins to skirt the river valley, it appears to be associated with limonite. The vein has not yet been searched for in the wooded district lying east of the river.

This vein is, strictly speaking, a stratum-vein, and maintains a course very closely agreeing with that of the slates, and a nearly vertical dip. During a great part of its course, as sketched above, it runs on elevated ground, which would facilitate mining. There are indications of a similar parallel vein lying further to the south, but hitherto it has not received attention. The alternation of specular and limonite ores in these veins has also been observed at Londonderry, Colchester County, where the earlier workings at several points yielded considerable quantities of the former ore, while at greater depths limonite alone is found.

The ore is compact and foliated, and its quality is shown by the following analyses:

| Composition. | Specular Ore. | | | Limonite. |
|---|---|---|---|---|
| | I. Weaver. | II. Weaver. | III. Watson. | IV. Drug Brook. |
| Iron oxides, | 92.01 | 97.52 | 93.80 | 81 902 |
| Manganese oxide, | 2.16 | .... | .... | .068 |
| Alumina, | .21 | .... | .... | 1.019 |
| Lime carbonate, | 1.27 | .... | .... | .313 |
| Magnesia carbonate, | .43 | .... | .... | .052 |
| Phosphoric acid, | .08 | .... | trace. | .... |
| Phosphorus, | .... | none. | .... | .431 |
| Sulphur, | .16 | trace. | .68 | .046 |
| Titanic acid, | trace. | .... | .... | .... |
| Silica, | 3.68 | 3.20 | 3.40 | 6.350 |
| Moisture, | .... | .... | .... | 9.462 |
| Metallic iron, | 64.41 | 68.33 | 65.60 | 57.718 |

I. Dr. Stevenson Macadam. II. Dr. T. E. Thorpe. III. E. G., Jr. IV. Geol. Sur., Canada.

The Upper Silurian district is marked by the occurrence of beds of red hematite, some of which reach large dimensions. Allusion has already been made to the basin-shaped synclinals presented by these strata. One of these synclinals in Blanchard settlement has a width of one and a half miles, and a length of about three and a half miles. Owing to the wooded character of much of the ground at this point, the exact thickness of the basin cannot be given. Its western apex rests on a mass of the indurated slaty breccia, already alluded to, and has been for a short distance a good deal broken by faults.

On the southern side of this basin, a bed of ore from 3 to 5 feet in thickness has been traced for about three miles, and maintains a moderate dip to the north. The reverse outcrop, or southerly dip, of this bed has been observed at several points on the north side of the basin, and several beds of ore are believed to occur between them in the flat-lying band of measures forming the axis of the synclinal. About 700 feet below the northern outcrop of this bed is an exposure of a bed of red hematite, commonly known as the Big Blanchard bed. This bed stands nearly vertical, and varies in width from 30 to 100 feet. No attempts have yet been made to trace it beyond its natural exposure, which is about half a mile in length.

At a vertical distance below the southern outcrop of the upper bed, corresponding closely to the distance between it and the big bed on the north side, are strong surface indications of the reverse outcrop of the big bed. Should this bed be proved to extend over the area indicated it would yield an immense amount of ore. The northern end of this synclinal is broken by faults bringing up lower measures; and a little further north the Webster red hematite is met with, a strike nearly at right angles to that of the beds just described, and a northerly dip at angles of 15° to 50°.

The exact relationship of the Webster ore to that of Blanchard has not yet been clearly made out, but it may be taken to represent one of the outcrops of the big bed brought up by a transverse folding. It has been traced for about four miles, and varies in thickness from 15 to 40 feet. The best ore extends for about one mile each way from Sutherland's River, and the bed then becomes poorer by degrees from excess of silicious matter, until it passes into a ferruginous quartzite. At several points, beds of quartzite are found intercalated in the ore, but do not pass into it, being sharply defined by smooth partings. This ore is not fossiliferous, and may be con-

sidered a segregation of iron oxide around minute grains of silica, giving the ore in places a sub-oölitic structure. Its color is steel-gray, with a metallic luster in some of the layers. The ore is very favorably situated for mining as it runs on the crest of a high hill.

About three miles to the north, after several small synclinal folds are passed, the Fall Brook ore is met. It has a southerly dip and resembles the Webster ore, but is of an earthy red color. It has been opened by Mr. Watson at Fall Brook, and is known to extend about five miles to the eastward, nearly to the spathic ore on McLaren's Brook. Its thickness is about 15 feet, and it preserves the quality, shown by an analysis of the ore from the opening in Fall Brook, over the greater part of its course. To the south of the spathic ore deposit it becomes more silicious, and freer from sulphur and phosphorus.

There are several other smaller areas of this class of ore in the district under consideration, but they have not yet been examined. The measures of this horizon continue with a few breaks from Springville to Arisaig, on the east line of the county, a distance of forty miles. They have been examined at several points, and have yielded indications of the presence of red hematites. At Arisaig a bed of red hematite similar in appearance and structure to that found at Webster's, and 4 feet in thickness, has been traced for some distance.

The following analyses will show the character of these ores:

| Composition. | I. Webster. | II. Webster. | III. Fall Brook. | IV. Arisaig. |
|---|---|---|---|---|
| Iron oxides, | 75.67 | 65.26 | 63.451 | 74.77 |
| Manganese oxide, | .52 | traces. | .... | trace. |
| Alumina, | .45 | 5.59 | .205 | .... |
| Lime carbonate, | 2.44 | 1.88 | 3.992 | 8.76 |
| Magnesia carbonate, | .98 | 1.05 | .120 | |
| Phosphoric acid, | .22 | .... | .450 | .... |
| Phosphorus, | .... | none. | .... | .08 |
| Sulphur, | .29 | none. | trace. | trace. |
| Titanic acid, | trace. | .... | .... | .... |
| Silica, | 19.43 | 23.68 | 27.735 | 16.10 |
| Moisture, | .... | 2.54 | 2.995 | .... |
| Metallic iron, | 54.36 | 43.40 | 44.400 | 52.34 |

I. and II. Drs. Macadam and Thorpe. III. E. G., Jr.

It may be remarked that the amount of phosphorus in these ores appears to be connected with the presence of fossils at certain places.

When they are absent or present in small numbers, as is usually the case, the beds yield an ore very free from both sulphur and phosphorus.

Although the grade of these ores may not be equal to that of the specular, they are evidently in enormous quantity and can be very cheaply mined; and the more northerly beds are close to the coal-field.

The ores next to be noticed are the limonites of the East River valley. From Springville to Sunny Brae the Lower Carboniferous Marine limestones rest on the Upper Silurian and lower strata, the points of junction presenting at several places interesting sections of the deposition of the limestones on the clay-slates and other pre-Carboniferous rocks. The line of junction is at many points occupied by deposits of limonite, varying in thickness from 3 to 20 feet. At some points the ore-bearing ground appears from surface indications to be several hundred yards broad. At several openings the ores are highly manganiferous, and specimens of pyrolusite of good quality have been found. The limestones connected with these ores at Springville and Black Rock are, in some instances, rich enough in carbonate of iron to be available for furnace-use.

The source of these bodies of ore may be sought for in the oxidation and concentration of the iron in the limestones, and from the beds of red hematite in the Upper Silurian already referred to, several of which are in the immediate vicinity of the limonite.

The ores are compact, mammillated, and fibrous, and their quality is shown by the following analyses:

| Composition. | I. | II. | III. | IV. |
|---|---|---|---|---|
| Iron oxides, | 88.92 | 93.09 | 81.19 | 48.223 |
| Manganese oxide, | .78 | 1.10 | .20 | 14.410 |
| Alumina, | .71 | .... | .... | .... |
| Lime carbonate, | 1.44 | .... | .... | .015 |
| Magnesia carbonate, | .82 | .... | .... | traces. |
| Phosphoric acid, | .34 | .... | .15 | .... |
| Phosphorus, | .... | none. | .... | .020 |
| Sulphur, | .24 | .04 | traces. | .480 |
| Titanic acid, | trace. | .... | .... | .... |
| Silica, | 2.14 | 4.80 | 4.26 | 25.130 |
| Moisture, | 4.61 | .... | 13.60 | 12.530 |
| Metallic iron, | 62.24 | 65.20 | 56.83 | 33.826 |

I. Dr. S. Macadam. II. Dr. T. E. Thorpe. III. J. H. Huxley. IV. E. G., Jr.

Passing to the Sutherland's River district, an opening has been made on a bed of spathic ore which occurs in red marl, associated

with limestone and gypsum. Its width varies from 6 to 10 feet, and from surface indications it appears to extend over a considerable tract of country. The bed in places is highly manganiferous, and is a typical spathic iron, granular and crystalline in texture, and of a light-gray color. The following analyses will show its character:

| | I. | II. |
|---|---|---|
| Sesquioxide of iron, | 20.52 | —— |
| Carbonate of iron, | 57.40 | 82.11 |
| Carbonate of manganese, | 8.29 | 4.70 |
| Carbonate of lime, | 4.02 | 2.37 |
| Carbonate of magnesia, | 5.66 | 9.06 |
| Silica, | 2.38 | 1.69 |
| Moisture, | 1.43 | —— |
| Sulphur, | none | .10 |
| Phosphorus, | none | none |
| Metallic iron, | 42.07 | 39.64 |

I. Dr. T. S. Hunt. II. J. H. Huxley.

Indications of spathic ore have been found on Sutherland's River, McLaren's Brook, etc., under similar conditions, and this ore may prove a widespread and important addition to the ores of the county.

Still further east on French River, at a horizon apparently several hundred feet higher, and considered to represent the upper part of the Marine limestone formation, there are several beds of a nodular red hematite, varying in thickness up to 4 feet. These beds have been recognized as extending for several miles. They appear to be the weathered outcrops of carbonate ores, but they have only been examined superficially. Samples taken from the outcrop of a 4-foot bed on French River yielded 35 per cent. of metallic iron.

In the productive coal-measures, clay-ironstones and black-band ore have been noticed at several horizons. It may be questioned if any of the ores hitherto casually exposed in shafts and stone tunnels are present in quantities large enough to warrant the expectation of independent workings, although in some cases they could be worked in connection with the coal-beds. The horizon yielding these ores most abundantly appears to be that embraced between the Albion main seam and the McGregor seam. Old records show several beds included in these strata which contain layers of ironstone up to 3 feet in thickness, and on further examination they may prove of economic value.

The following analyses by the writer will serve to show the quality of some of these ores:

| | I. Clay-ironstone. | II. Black-band. |
|---|---|---|
| Moisture, | 2.132 | —— |
| Sulphur, | .612 | .214 |
| Phosphoric acid, | trace | .586 |
| Manganese oxide, | —— | 4.450 |
| Lime, | trace | 3.780 |
| Magnesia, | 1.655 | .783 |
| Alumina, | 16.962 | 3.180 |
| Silica, | .780 | 16.546 |
| Carbonic acid, | —— | 27.589 |
| Iron protoxide, | 45.361 | 36.000 |
| Metallic iron, | 35.000 | 28.000 |

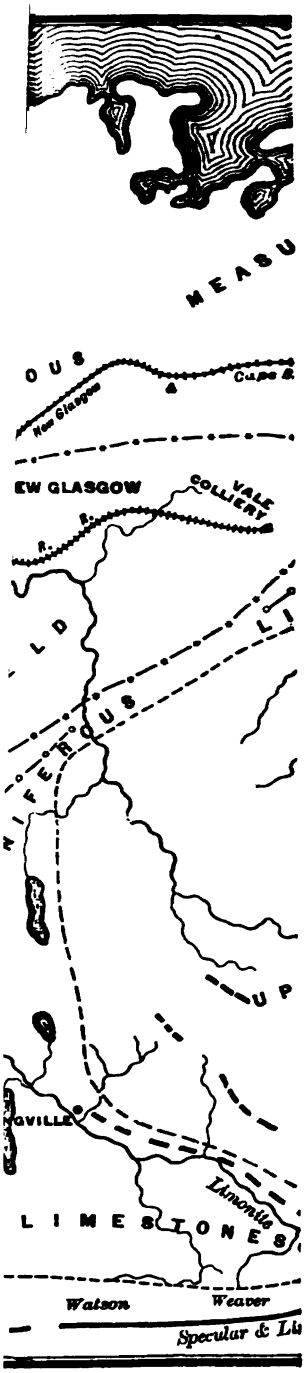
Although no attempts have yet been made to find iron-ore in the coal-districts, the indications observed up to the present date may fairly be considered to show the probable presence of a large and cheap supply of ore.

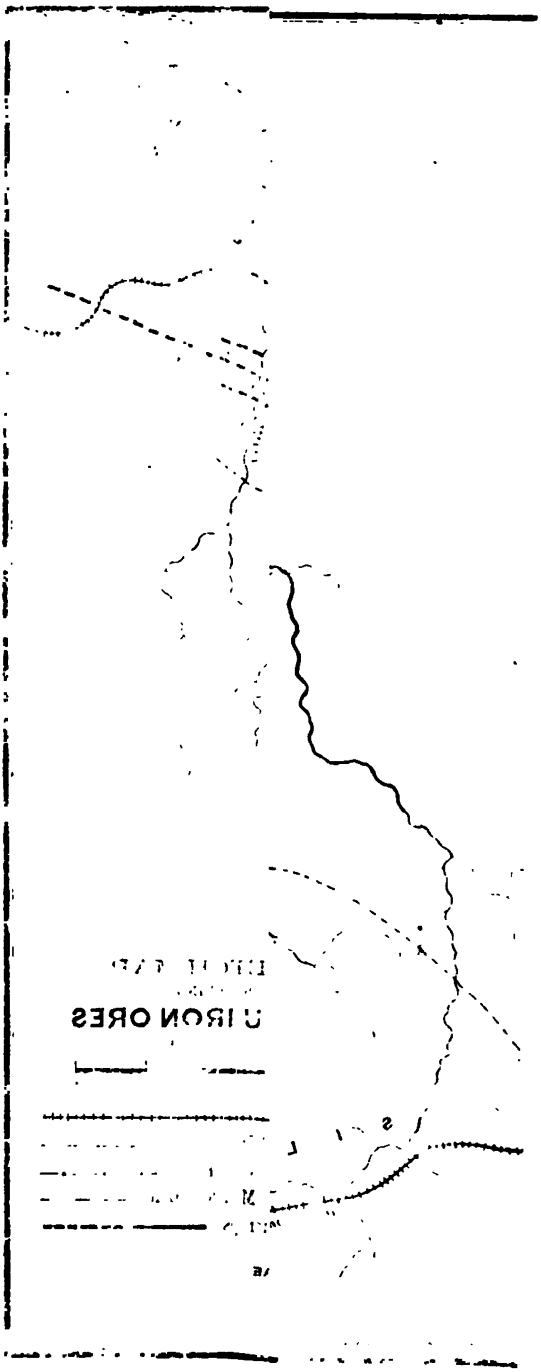
In the Upper Carboniferous measures lying to the north of New Glasgow there are several thin layers of clay-ironstone, not apparently of economic value.

In the surface-drift there have been beds of bog iron-ore observed at numerous points. These deposits have nowhere been observed of large dimensions, but would probably be utilized for furnace purposes in the vicinity of the iron-ore districts more particularly alluded to above. River John, French and East rivers may be mentioned as localities yielding this ore; and the following analysis is of ore from a small bed exposed in a cutting of the Glasgow and Cape Breton Railway in Merigomish, near French River:

| | |
|---|---|
| Moisture, | 5.500 |
| Water of composition, | 6.100 |
| Sulphur, | .208 |
| Phosphoric acid, | .384 |
| Manganese oxide, | 5.886 |
| Lime, | trace |
| Magnesia, | trace |
| Alumina, | 3.106 |
| Silica, | 12.325 |
| Iron peroxide, | 66.510 |
| Metallic iron, | 46.557 |

These notes may serve to give a general idea of the iron ores of Pictou County, and considering the wooded condition of nearly all the Silurian and Cambro-Silurian districts, and the little inducement that has as yet existed to stimulate search, it must be admitted that the discoveries hitherto made, almost exclusively of natural


MEASU
OUS
New Glasgow
Cape B.
EW GLASGOW
VALE COLLIERY
R.
R.
LD
LI
NIFEROUS
UP
NGVILLE
Limonite
LIMESTONES
Watson
Weaver
Specular & Li



exposures, are of good promise. It is anticipated that the work of the Canadian Geological Survey will shortly be extended into this county, and their mapping of the divisions of the pre-Carboniferous rocks will undoubtedly facilitate the prospector's work.

In this connection a brief reference to the two important accessories to iron smelting—fuel and fluxes—may not be out of place.

The coal of Pictou County may be described as bituminous and free-burning. Several of the seams now worked have not been found to yield a good coke, but answer well in the furnace when used with about twice their weight of coke. Other seams, however, yield a coke which makes a good furnace-article, and has been successfully used at Londonderry. The coke is cellular, and extremely resistant, resembling in appearance that from the north of England. The following average of several analyses, made some years ago by the writer, will serve to show its character:

| | |
|---|---|
| Moisture, | .96 |
| Carbon, | 83.85 |
| Sulphur, | .52 |
| Phosphoric acid, | .01 |
| Ash, | 14.50 |

Limestone is abundant in the county, and forms an irregular band between the iron-ores and the coal-field. On the East River, and on its western branch, it is at several places close to the iron-ore. The lowest beds hitherto found rest on the pre-Carboniferous rocks, and are generally highly ferriferous and manganiferous. They form a horizon which I have described in a paper read before the last meeting of the Royal Society of Canada as presenting itself at the base of the Marine limestone formation in Nova Scotia, and at many points yielding ores of manganese, iron and lead. The higher beds are frequently very pure and uniform in quality. They vary in thickness up to 75 feet, and are often continuous for long distances.

The following analysis will show the character of one of the better-known beds:

| | |
|---|---|
| Carbonate of lime, | 93.90 |
| Carbonate of magnesia, | 2.45 |
| Peroxide of iron, | .59 |
| Peroxide of manganese, | .56 |
| Alumina, | .12 |
| Sulphur, | .03 |
| Phosphoric acid, | .03 |
| Silica, | 2.10 |
| Moisture, | .18 |

## *THE MICROSCOPIC STRUCTURE OF IRON AND STEEL.*

BY F. LYNWOOD GARRISON, PHILADELPHIA, PA.

It is not intended to make in the present paper any deduction or to formulate any theories from the results obtained by experiments. The further expenditure of considerable time and labor would be required to obtain a sufficient basis for positive assertions as to the microscopic structure of the different varieties of iron and steel, and the structural changes which take place in them. It is therefore my purpose at this time to offer simply a synopsis of the general results arrived at in a few months' work, a brief description of apparatus used, and a few hints as to the preparation and preservation of the material which it is intended to investigate.

The study of the microscopic structure of iron and steel is not altogether new. Some attention has been given it in both England and Germany. But the foreign publications on the subject have thus far been confined, so far as I am aware, to two papers, one by Herr Martens, of Berlin, contributed to the *Verein zur Befoerderung des Gewerbfleisses* and the other a lecture by Dr. H. C. Sorby of Sheffield. Dr. Sorby, it seems, was induced to investigate the subject as bearing on the structure of meteoric iron; and the results he obtained are certainly very interesting. At the Boston meeting of this Institute, in February, 1883, Mr. J. C. Bayles called attention to the subject in a neat and exceedingly interesting paper, in which the work of Messrs. Martens and Sorby was summarized,* and original suggestions were added.

It is at present difficult to say what will be eventually the practical value of the microscope, thus employed, in the sciences of engineering. The *rôle* which it seems most likely to play is that of an adjunct to the testing-machine, and not (as some have supposed) a rival to the chemical laboratory. That it will be a most valuable accessory seems, to say the least, highly probable.

I need hardly go at length into the details of preparing the material for examination. Mr. Bayles has described the process in such a plain and comprehensive manner that if his instructions are

* *Transactions*, vol. xi., p. 261.

carefully followed, one need not encounter any serious obstacles after a little experience and the expenditure of a considerable amount of time and patience. Patience and cleanliness are the two most important attributes to be acquired by a student, if he desires success in work of this character. A deficiency in either will be sure to spoil his work, and in the end he will give it up in disgust wondering what has been the cause of his failures.

In grinding the specimens, it is quite unnecessary that they should be ground to an extreme thinness and mounted in Canada balsam as microscopical objects are usually preserved. This entails a vast amount of labor, to no end whatever. A good and accurate photograph, once obtained, is usually sufficient for any reference that might be desired in the future; besides, with a little care the etched surfaces of the objects can be preserved from rust by simply rubbing a few drops of kerosene oil over them with a soft chamois-skin and then placing them in a tightly corked phial.

The size of the objects to be examined under the microscope, may vary considerably; but the sizes found most convenient range from $\frac{1}{4}$ down to about $\frac{1}{16}$ of an inch in thickness and from an inch to $\frac{1}{4}$ of an inch in sectional area. If the specimens are extremely thin, there is often much difficulty in mounting them properly on a slide, and getting the etched surface perfectly parallel to the object-glass. After the surface has been sufficiently treated with acid, and shows under the microscope no further traces of scratches made in the grinding, it should be carefully dried and cemented to a glass slide with wax or cement, great care being taken to have it in the proper plane parallel to the object-glass: otherwise it will be impossible to make a satisfactory photograph.

The greatest difficulty encountered in pursuing the study of the structure of materials is that of making accurate and satisfactory records of what is seen under the microscope. To effect this the only accurate and quick means is to photograph. Hence the student must not only be a good microscopist, but also understand the theory and practice of photography, an accomplishment which every engineer will find it useful to acquire. The subject of photo-microscopy, although a comparatively new one, is somewhat extensive, and it would not be within the scope of this paper to enter upon it in detail. A few hints, however, may be of value. The camera should not be large; the most convenient size will be found to be one using $4\frac{1}{4} \times 5\frac{1}{2}$ inch plates, and having a bellows capable of being extended several feet. Instantaneous dry plates only should be

FIG. 1.

No. 3 gray pig-iron. × 50 diameters.

FIG. 2.

White pig-iron. × 20 diameters.

FIG. 3.

Longitudinal section of rolled bar-iron. × 45 diameters.

FIG. 4.

Cross-section of rolled bar-iron. × 45 diameters.

used, for experience has shown that no others will serve the purpose half as well; and they should be developed with a weak solution of an alkaline or a ferrous oxalate developer. It is found that when an instantaneous plate is used it is better to make a comparatively long exposure and use a weak developer than to make a short exposure and use a strong developer.* The time of exposure depends upon many conditions, such as the clearness of the atmosphere, the intensity with which the etched surface reflects light, the quality of the objectives, and the sensitiveness of the gelatine plate. The above conditions are frequently so complex that it would be impossible to say just how long the exposure should be made; the student must learn to judge this by experience. A safe limit, however, may be placed at not over 20 seconds, when good *direct* sunlight can be obtained and a perfectly instantaneous plate used.

The proper illumination of the object to be photographed under the microscope is somewhat difficult and requires considerable practice to effect it. It must also be borne in mind that the best results can be obtained only by direct sunlight, unobscured by clouds or mists. When the object to be photographed has been carefully adjusted on the stage of the microscope, and the focussing has been approximately made, the table (holding both the camera and microscope) is placed near the window, so that the sunlight may strike *directly* upon the object. The fine focussing is then made by means of a cord passing around in a groove in the periphery of the fine adjustment-screw of the microscope. The image on the ground glass should be perfectly clear and well-defined in all its details. To effect this, a focussing glass, such as is ordinarily used by photographers, may be used with advantage in adjusting the finer details. The use of a condensing lens depends upon the ability of the etched surface to reflect light. Thus, for instance, hard steel reflects light so well that a condensing lens is unnecessary, while in the case of pig-, cast-, or wrought-iron, its use is absolutely essential. For further particulars on this subject, Dr. Sternberg's work, *Photo-Micrographs and How to Make Them*, is recommended.

In selecting a microscope, though the question of cost is of primary importance to many, it should be remembered that a good instrument once obtained will, with proper care, last a lifetime. Such an instrument, under ordinary circumstances, should not cost less than

* A developer diluted to *one-half* its usual strength will be found to give excellent results.

$35 or $40, although a good second-hand one may be obtained for less. The most important points to be observed in selecting a microscope with which it is intended to take photo-micrographs are as follows:

1st. The stand should be of the best workmanship and material; there should be no "shake" or lateral motion; in the adjustment of the focus there should be no "lost motion"—that is, the focus should instantly change with the slightest motion of the milled heads—and for photography there *must* be a universal joint, for inclination.

2d. The instrument must be provided with a fine adjustment-screw with a groove turned in its periphery.

3d. The mirror under the stage should be so constructed that it can be made to swing over, around, and above the stage, thus affording a means of more intense illumination to the object than otherwise could be obtained with opaque substances. The objectives should be of the very best quality. Experience has shown that it is poor economy to use any others. Beck's $\frac{2}{3}$ inch and $1\frac{1}{2}$ inch will be found to give excellent results, and a range of powers quite sufficient for any ordinary work. There are a number of makers of objectives, all about equally good, but as I have used Beck's lenses only, I say nothing about the rest. Two great points to be observed in selecting an objective are, that it has a good "*penetration*" and an extra lens (to be used only when photographing), so that the visual and chemical foci may be made to coincide. The correction of Beck's is effected in the $1\frac{2}{3}$ inch by substituting for the back-stop a double convex lens of 8-inch focus and for the $\frac{2}{3}$ inch a double convex lens of 5-inch focus. Higher powers need no correction, and lower ones than $1\frac{1}{2}$ inch are rarely employed.

The quality of the eye-piece is of secondary importance, as it is never used in photographing. The attachment of a mechanical stage to the microscope is a great convenience and economizer of both time and patience, although it is not an absolute necessity. Dr. Carpenter's work and Dr. Phin's *Hints on the Selection and Use of the Microscope*, together with Dr. Sternberg's work, are recommended to those who may desire further details on the several subjects.

Of all the varieties of iron and steel, pig- and cast-iron are the most difficult to prepare for examination.

Fig. 1 represents a No. 3 pig-iron (gray) as it appears under a power of 50 diameters. The specimen was prepared and etched with the greatest possible care, so that it may be safely taken as a good example of pig-iron, ranging from No. 1 to No. 4, when magnified to

FIG. 5.

Longitudinal section of a bolt of Clapp & Griffiths steel. × 45 diameters.

FIG. 6.

Cross-section of a bolt of Clapp & Griffiths steel. × 45 diameters.

FIG. 7.

Crucible tool-steel. × 45 diameters.

FIG. 8.

File-steel. × 40 diameters.

that degree. It will be seen to consist of a heterogeneous mixture of metallic iron and long, narrow, black plates of graphite. It does not appear to bear the slightest trace of any crystalline structure. The straight black lines which seem to stand out in relief are the graphite plates. Owing to the comparatively high power used in this case, the slightest inequalities of the etched surface cause an unevenness in the focussing; hence the obscurity of some parts of the plate. By close observation of some parts, however, the structure and the graphite plates can be made out. In many cases of pig- and cast-iron the graphite plates seem the group themselves in bunches or lumps. This seems to be more characteristic of cast- than of crude pig-iron. It is not unlikely that the second melting and slow cooling enables the graphitic carbon to separate itself more readily in that way.

White pig-iron exhibits a highly crystalline structure, as will be seen in Fig. 2. The intensity of the crystallization depends very much upon the degree of chilling. Thus, in a large casting made in a metallic mould, the outer surface, which comes in contact with the mould, will be found to exhibit a high crystalline structure (such as shown in Fig. 2), while the inner part, which has cooled slowly, will show very little or perhaps no crystalline structure. This highly crystallized white iron exhibits even under a high power, only a comparatively small number of graphitic plates. The crystalline structure in some cases is irregular, while in others the crystals are regularly arranged with their long axes normal to the surface of the mould. The plates of graphite will be found to be arranged parallel to the lines of crystallization.

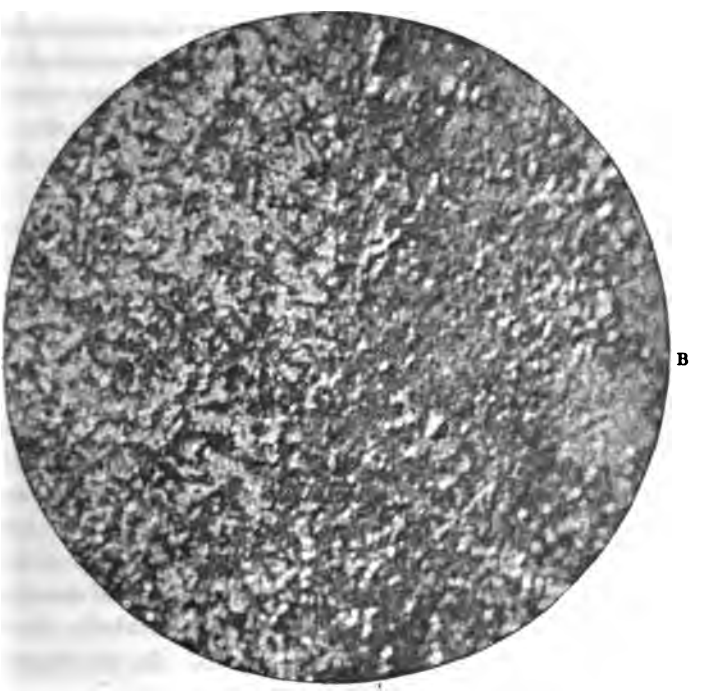
Wrought-iron or mild steel exhibits a fibrous structure, running in the direction in which it has been rolled. Fig. 3 shows the structure of a fine quality of rolled bar-iron. The fiber is distinct and shows numerous furrows and cavities, due to working and the presence of intermingled slag during the rolling. Wrought-iron (not steel) does not show, even under a power of one hundred diameters, the slightest trace of crystalline structure. It has been held by Percy and other authorities that the fibers were simply drawn-out crystals. I have tried in numerous instances to determine if such really was the case, and although I have examined many longitudinal and cross-sections of various grades, I cannot find that there exists any foundation for such a view.

Fig. 4 shows a cross-section of the same material as Fig. 3. The

FIG. 9.

Meteoric iron. 20 diameters.

FIG. 10.




"Burnt out" grate bar of cast-iron. (A.) The cast-iron unaltered by the action of the fire. (B.) The cast-iron changed into hard *steel* by the action of the fire. × 45 diameters.

furrows of Fig. 3 will be seen to be replaced by irregular cavities in the cross section.

Figs. 5 and 6 show, respectively, a longitudinal and a cross-section of a bolt made of Clapp & Griffiths steel. The difference in structure between iron and steel can be readily seen in this case, the latter showing a fibrous and yet finely granular structure, characteristic of steel.

Hard or tool-steel presents a structure entirely different from any of the preceding. It is highly crystalline, uniform in structure, and shows no lines of weakness or any tendency in the crystals to develop themselves in any given direction. Fig. 7 is a high-grade crucible tool-steel magnified 45 diameters.

Fig. 8 is the usual grade of file-steel magnified to the same degree. The latter differs from crucible tool-steel only in being somewhat more compact and harder. All steels exhibit a similar characteristic structure, which enables a person, with practice, to judge of their relative qualities by a simple comparison of their compactness, luster, and crystalline structure.

Fig. 9 shows the structure of meteoric iron, which is quite different from any of the artificial irons or alloys of iron and nickel. The peculiar lines so prominent in the figures are characteristic of meteoric-iron and are commonly known as "Widmannstatten lines." I have not been able to detect these lines in all varieties of meteoric iron. It seems that if the iron be very impure and contain but a small amount of nickel, there is little or no tendency to develop them.

One of the most interesting and peculiar changes of iron into steel which have came under my notice in connection with this subject, is exhibited in Fig. 10. It shows a section made from a "burnt-out" grate-bar of ordinary cast-iron. The left hand side (A) shows the cast-iron unaltered by the action of the heat; the right side shows where the cast-iron has been completely changed to hard steel, which resists the file quite as much as any tool-steel. On examination of the part of the bar which came most in contact with the fire, I found that the entire surface was changed to hard compact steel, with a thickness of about $\frac{1}{10}$ of an inch. The most remarkable point to my mind, is that the line of demarcation is so sharply defined, thus showing little or no intermediate stage of decarbonization. The altered part (B) shows a structure decidedly characteristic of hard tool-steel (compare with Fig. 8). In the unalterable part (A) the structure of cast-iron is quite apparent, the groups and

clusters of graphite plates being readily distinguishable (compare with Fig. 1). As the reasons for such a remarkable change of structure might cause considerable speculation and much difference of opinion, it would perhaps be better to defer its discussion for another opportunity and a separate paper.

In conclusion, it is most earnestly desired that this paper may excite a friendly criticism and discussion of the subject, by which we may learn the opinions and experiences which others have had of the physical properties of iron and steel. From any persons interested, I should be very glad to receive such specimens or information as they may see fit to send.

---

## *A SIMPLE APPARATUS FOR DETERMINING THE RELATIVE STRENGTH OF EXPLOSIVES.*

BY S. WHINERY, SOMERSET, KY.

In these times of sharp rivalry, both as to price and quality, among the makers and venders of engineering explosives, it is often desirable to be able to determine the relative energy or value of the various explosives offered for sale, in order to purchase intelligently; or, having contracted for a large amount of an explosive of a certain standard quality, to be able to ascertain if the manufacturer keeps his product up to the specified standard. The simple and inexpensive apparatus described below was devised by the writer while engaged on the improvement of the Tennessee River, at Muscle Shoals, under the direction of Major W. R. King, U. S. Engineers, in the summer of 1879. It answered the purpose so well that it is thought that a brief account of it may be of interest to other engineers. It consisted, essentially, of an old blacksmith's anvil and a common striking hammer, such as is used for driving rock-drills. The anvil was placed face downward on solid, level ground. In what was then the top of it, a vertical hole, one and one-fourth inch in diameter and about one and three-fourths inch deep, was made with a ratchet-drill. The surface of the anvil immediately around the drill-hole was made as true and smooth as possible with a file.

Next, a new striking-hammer, weighing nine pounds, with a turned and true face, was selected; and a handle, eleven feet long and about one and a half inches in diameter, was fitted into it so that it

projected about one foot beyond the hammer. The long end of the handle was mortised into a wooden axle about three feet long, turning on half-inch iron pivots, in posts set securely in the ground, in such a position as to bring the face of the hammer symmetrically over and covering the hole in the anvil, and so that when raised upward it revolved in a vertical plane perpendicular to the face of the anvil. Light horizontal wooden braces, extending from the ends of the axle to a point about half-way along the handle, secured the latter in position, and gave it additional stiffness. To further secure the hammer from lateral motion, the forward end of the handle, which projected beyond the hammer, had a vertical slit sawed nearly its full length, and was placed astride of a stout vertical wire secured tightly to arms projecting from an upright post; but this arrangement was probably unnecessary, and the friction between the wire and the wood doubtless detracted somewhat from the accuracy of the machine.

If, now, a small charge of any explosive be placed in the drill-hole, or firing-chamber as it may be called, the hammer adjusted to its place, covering closely the mouth of the hole, and the charge fired, the hammer will be thrown to a height proportional to the quantity and strength of the explosive used; and if equal charges of different explosives be successively fired, the heights to which the hammer is thrown will bear the same ratio to each other as the respective energies of the samples fired, and may be taken as a relative measure of the strength of each.

The essential parts of the apparatus were now complete, and it only remained to devise a ready means of firing the charges, and measuring the height to which the hammer was thrown. For firing the charge, an ordinary platinum fuse, exploded by a Laflin and Rand magneto-machine was used. Two spring-clips, made of tin, and fastened to the upright post mentioned above, were connected by wires to the poles of the magneto. When the fuse and charge were in place and everything ready to fire, the bare ends of the fuse-wires were slipped into the spring-clips, and the circuit thus completed through the fuse. The wires of the fuse passed into the firing-chamber through a small notch or groove, filed into the face of the anvil, under the hammer.

To measure the height to which the hammer was thrown, a light index-arm of wood, about ten inches long, was screwed to the top of the handle, just back of where it entered the hammer (the handle being left square at this point for the purpose), in such a manner as

to allow it a slight horizontal motion. The outer end of this index arm was slit vertically with a saw, and passed astride of a fine vertical wire held in place by arms from an upright post. This wire carried, above the index arm, a small cork moving with just enough friction to hold it in whatever position it might be left. Lastly a rod, graduated into feet, tenths, and hundredths, was fixed to the upright post so that its zero corresponded to the top of the cork when everything was in position for firing. When the charge was fired, the index arm carried the cork with it to the highest point reached, where it remained until its position was read off on the graduated rod.

A simple device for interposing a block of wood between the anvil and the hammer, as the latter fell back after firing, to prevent the battering of the face of the anvil, was also attached, but was probably unnecessary.

It was thought that by making the handle of the hammer so long, and using small charges of explosives, the path of the hammer might practically be considered a straight line, instead of a circle; but this did not prove to be the case. As the index-wire was tangent to the circular path of the hammer, the reading taken represented the tangent of the circular angle described by the hammer in its flight; but the true vertical height reached by the hammer was represented by the *sine* of that angle, and this sine and tangent were found to differ sufficiently to make it necessary to apply a correction to the index readings. This was easily done, since, the radius being ten feet, the corrected readings could be taken directly from a table of sines and tangents.

It is evident that only the dynamical work done by the charge in exploding, is shown by this machine, and consequently its results would not correctly represent the relative value, for engineering purposes, of slow and rapid burning explosives, such, for instance, as blasting powder and dynamite. It should, therefore, only be used to compare explosives of the same general class.

The explosives experimented with at Muscle Shoals all belonged to the dynamite family. The charges used were generally ten grains of the number one class, or twenty grains of the number two class of dynamites. Each charge was weighed out as carefully as possible on a superior prescription-balance (which turned readily with one-fourth grain), and wrapped in tissue-paper. Usually from ten to twenty charges were prepared from each sample to be tested. When all was ready, a platinum fuse was placed in the firing-cham-

ber, a charge dropped in with it, the hammer and index-cork adjusted to their places, the battery connected, and the charge fired. From thirty to forty charges could be readily fired in an hour. It was, of course, necessary first to determine the average height to which a platinum fuse alone would throw the hammer, and this constant, when determined, was subtracted from the average height to which the hammer was thrown by the charge and fuse together.

The effects produced by equal charges of the same explosive were as uniform as could be expected from so crude an apparatus. In fact the records compare very favorably, in this respect, with those of the more exact experiments made by General Abbott and others, with far more expensive and carefully made apparatus; and by taking the average of from ten to twenty tests, first throwing out such readings as were, from accidental or other causes, manifestly wrong, the results doubtless represented fairly the relative value of the explosives thus tested.

---

## *COLORED MINING LABOR.*

BY ALFRED F. BRAINERD, BIRMINGHAM, ALA.

HAVING had considerable practical experience in the management of colored mining labor in the South, I have thought a few observations upon its peculiarities might interest those not personally familiar with it. In mining, as in all other departments throughout the South, this class of labor is largely in excess of any other; and its characteristics need to be known and duly taken into consideration by those who may be charged with the conduct of southern enterprises.

The colored laborers are fervently religious, intensely superstitious, improvident, and usually good natured and happy,—in a word, they are like children. That strong religious emotions do not involve necessarily a moral sense highly developed in the direction of ethics, is shown in the propensity of the colored population for chicken-stealing, and in the brutal fights and other outbreaks of which they are not infrequently guilty, upon any slight provocation. It is only fair to say, however, that many individuals among them are in the highest degree steady and trustworthy.

To one accustomed to seeing white miners at work in the middle, northern or western States, the colored miners seem somewhat slow and lazy. But their efficiency is greater than it appears to be. The almost tropical sun of midsummer beats upon their unprotected heads

without injuring them. Sunstrokes are practically unknown among them. What they may lack in speed they make up in muscular efforts and in longer hours of labor. It is quite common in "open work" on ore-veins or in quarries, for the colored laborers to enliven the monotony of their task by singing some melody, keeping time with their hammers, picks, and shovels to the music. One never hears as yet of strikes among them. Yet they hang together with exceptional loyalty. In case of mishap due either to accident or carelessness, the management fails to get at the cause by examining any number of them. They always manage to get together and agree as to the story they will tell if called upon. Among white miners, on the contrary, there is usually some one to turn "States' evidence," either for the sake of getting out of the difficulty himself, or of getting some one he dislikes into trouble, or from the higher motives of truth and duty.

The system of payment in checks or scrip, similar to that used in the middle States, is common. This enables the miner to get provisions every evening at the store. At the end of the month, rent, doctor's bill, and the amount of scrip drawn, or money advanced, are deducted from the amount due for wages, and the balance is paid in cash. Many of the miners live on from $3.50 to $7.50 per month. Most companies employ their own physicians, and the employees are taxed to pay the doctors' salaries and the cost of medicines used. A few of the colored miners lay up a certain amount every month from their earnings. Most of them keep in debt to the storekeeper, or simply draw enough to support themselves as they go along, and on pay-day receive the remainder and spend it within a short time in some foolish manner. They do not seem to care for improving their personal appearance by suitable clothing.

Mining operations for iron-ore in the South are usually conducted at or near the surface. A few companies only are mining iron-ore under ground. One of the most extensive underground ore mines is that of the Lowmoor Iron Co. of Virginia. At Rising Fawn, Ga., at the mines in the fossiliferous red ore-beds near Birmingham, Ala., at the Inman and Rockwood mines, Tennessee, underground work is done, almost wholly by adits, usually called "tunnels." Among the principal surface-mines of iron-ore are the Iron Mountain mines, near Covington, Allegheny Co., Va., the Stack mines in the same county, the Ingham and the Milnes mines, Page Co., Va., D. S. Cook's mines at Wilton, on the R. & A. R R., the Houston mines, Botetourt Co., Va., and the Crozer and the Rohrer mines in Roanoke Co., Va. In the Georgia and Alabama mines

above mentioned, there is a good roof or capping of rock which requires little timbering.

It is often very hard at first to get men to work underground in a section where most of the mining is on the surface. It is amusing to see a new applicant for a "job," in his anxiety to work in the "cut," due to fear of accidents and darkness in the tunnel. After he has worked in the cut for a while in all weathers, the inconveniences of mud and rain turn his attention to the superior comfort of the miners who work in the tunnel. He then wants to go inside too; and it thus becomes difficult to keep a force of men outside to do the necessary work. After a man has worked underground for a time he never works outside from choice.

Should a fatal accident occur in the tunnel, the miners will all leave that place and can scarcely be induced to work there again, even although the mishap may have been caused by carelessness or neglect, and not by any permanent source of danger. Men unacquainted with the locality have to be put to work there, and the former workmen have to be put into another tunnel.

A trying time to the manager of a mine occurs about the holidays, when nearly every man on the place wants to go home—and does go. This exodus generally begins about the 1st of December and lasts until the 1st of January. The majority of the absentees stay away from one to three months, during which time there is a partial or total suspension of mining. The only remedy for this seems to be is to induce men to bring their families to the place where they work and to provide suitable quarters for them.

The wages of colored miners in Virginia average from 90 cents to $1.00 per day of from 10 to 12 hours. In Tennessee, Georgia, and Alabama, from 80 to 90 cents per day of from 11 to 12 hours is paid. The cost of brown hematite in Virginia averages $1.85 per ton at the furnace; in a few cases, as high as $2.00 per ton of washed ore. Limestone costs from 50 to 75 cents per ton. In Tennessee ore costs about $1.65 at the furnace, and limestone 50 cents. In Georgia the average prices are about $1.50 per ton for ore and 50 cents for limestone; in Alabama about $1.25 for ore and 50 cents for limestone. There are two furnaces in Alabama which have a contract for five years, and are being supplied with ore at 75 cents per ton, delivered into the top of the furnace, at the rate of about ten thousand tons monthly. The coke procured in Tennessee, Georgia or Alabama is not as good as in Virginia, owing to less pains being taken with the coal at the ovens.

## *THE UTILIZATION OF THE IRON AND COPPER SULPHIDES OF VIRGINIA, NORTH CAROLINA AND TENNESSEE.*

BY C. R. BOYD, WYTHEVILLE, VA.

THE sulphuretted ores of Carroll and Grayson Counties, Va., Ore Knob, Ashe County, N. C., and Ducktown, Tenn., in their general position, are in the prolongation of the same massive deposits. The existence of the extensive ore-bodies has been well-established, not only in a practical way, but by the careful research of a number of men of science, including Dr. T. S. Hunt, Professor Kerr, Dr. Genth, Rogers, Safford, Professor Egleston, Dr. H. E. Colton, the writer, and others, and described in one or more of the volumes of our *Transactions*, as well as in other publications. The greater quantity of these ores being pyrrhotite, although much of them carry non-magnetic disulphide, their reduction on the ground will probably lead to better results than an attempt to mine and ship them to distant places; and their use as sulphuric acid producers, to be employed in the cheap manufacture of valuable fertilizers, will be chiefly the subject of this paper.

The great deposits of Carroll County, Va., are now nearer to railway transportation than any of the others, being six to eight miles from the Cripple Creek extension of the Norfolk and Western Railway, now being constructed, the grading of which is in an advanced state of completion.

I am not able to state what are the present prospects of an early completion of the contemplated line of railway to Ducktown. For a long while, during the time those deposits were mined and reduced for their copper, the works were forty miles from any railway; and the same may be said of Ore Knob, N. C.

The deposits in Carroll and Grayson Counties, Va., being now the most accessible to cheap transportation, will naturally claim the greater part of our attention; though it may be pertinent to remark, just here, that the ores of Ducktown, like those of Carroll and Grayson, Va., exist in the undecomposed levels as iron and copper sulphurets, much of which is a non-magnetic disulphide, as stated, with occasional exhibits of sulphides, such as covellite, erubescite, etc. There are, now and then, small quantities of silver, lead, and zinc,

no arsenic and 0.70 to 1.10 per cent. nickel; and no assays have been so far reported, the purpose of which was to determine whether tin is present in any of the veins or not. These ores range in their contents of copper from 1.70 to 5 per cent. for averages, copper pyrites often occurring in handsome bunches nearly pure; 38 to 46 per cent. of sulphur, and about 50 per cent. of iron. The average thickness of the ore-deposits, between hanging- and foot-walls, is from 26 to 100 feet and more. Their dip is usually from 45° to vertical; sometimes presenting the appearance of a distinctly bedded vein, at others that of true fissure, filled with pyrites in the usual manner, with light intrusions of quartz, talco-mica, and, doubtless, small quantities of calc spar.

It being reduced to a certainty, from experience, that these ores can be mined and dumped on the surface at 60 cents per ton of sulphuret, so great a quantity as exists in the twenty miles length of the veins in Carroll, Va., to say nothing of the others for the present, must very soon command the earnest attention of those who are now or will be engaged in the cheap manufacture of the more valuable fertilizers produced from phosphate-rock by means of sulphuric acid; in the reduction of ores containing silver or gold, in which sulphides of iron and copper may be employed, and in the production of copper metal.

Possibly the most extensive and lucrative industry will be the manufacture of fertilizers containing from 8 to 15 per cent. of available phosphoric acid, using the sulphuric acid made on the ground from these pyrites of iron and copper.

Of this class of fertilizers there are now consumed annually in the Southern States east of the Mississippi, about 750,000 tons; and, in the whole country about 2,000,000 tons, with the demand constantly on the increase.

Obtaining, first, the sulphuric acid from these ores, by either the common process, in the leaden chamber, or by the interesting method of Roessler, explained in volume xii., p. 274, *Transactions* of this Institute, and in London *Engineering* of April 17th, 1885, by Mr. Arthur F. Wendt, by which copper sulphate may also be obtained in quantity (100 tons of the ore yielding 55 to 75 tons of sulphuric acid), this acid is then used upon the phosphate rock, which holds a high and often variable percentage of phosphoric acid, leaving it in such a condition that it is ready for the conclusion of the process by which it is manufactured into a fertilizer, having such constituents, and in such proportions as are required for use in commerce, either as a high- or a low-grade superphosphate.

The phosphate-rock may be considered to hold the following ingredients:

| | |
|---|---|
| Phosphate of lime (as tribasic phosphate or orthophosphate), | 50 to 80 pr. ct. |
| Carbonate of lime, | 20 to 25 " |
| Sesquioxide of iron, | 1 to 3 " |
| Alumina, | 1 " |
| Silica, | 0.13 " |
| Organic matter, | 0.04 " |
| Water, | 1.40 " |
| Chloride of sodium, | 0.33 " |

The whole process of the reduction of the rock and conversion into the final product results in the preparation of a fertilizer holding 8 to 15 per cent. of available phosphoric acid and 2 to 4 per cent. of ammonia and potash, worth, according to its available phosphoric and ammoniated constituents from $30 to $50 or $60 per ton, while the cost of production, as will be shown, can be reduced to a figure surprisingly low, if not the lowest.

It would be interesting to describe the entire process of reduction and preparation; but there is scarcely space to do more than call attention to the fact that the cost of obtaining the sulphuric acid from the ores mentioned, as well as the whole cost of producing the fertilizers, will probably be fully compensated by the amount of copper sulphate, iron sulphate, iron and metallic copper produced at the same time, above the quantity of such of these reagents as may be required in the manufacture of fertilizers. For we must remember that from Roanoke, through Montgomery County, Va., to these Carroll and Grayson mines, there are several extensive bodies of ores, yielding from $15 to $25 per ton of silver, and on Brush and Laurel Creeks, in Montgomery and Floyd Counties, extensive gold deposits, yielding per ton of rock $15 to $50, as well as in some counties of East Tennessee, in the reduction of which the sulphates of copper and iron will be useful. (See the interesting papers in vol. xi. of W. Lawrence Austin, Ph.D., pp. 91–104, and Richard P. Rothwell, pp. 191–196; also, accounts of Mears' process, in which sulphuric acid is also used, and many others.) Now, owing to the fact that the Norfolk and Western Railway is carrying to Norfolk and Lambert's Point, on deep water, from Pocahontas, a large and constantly increasing quantity of coal to supply sea-going steamers and the general trade, the cars returning to Southwest Virginia, will take South Carolina phosphate rock and the recently discovered coprolites of the Virginia Peninsula, in ballast, at a very low rate.

The cheapness of production of the sulphuric acid, the low rate of transportation, and the possible utilization of by-products in several other paying metallurgical operations, besides those mentioned above, such as the conversion of the kettle salt-cake now accumulating at Saltville, near by, into soda ash, conspire to render the locality under consideration one of the most favorable in the whole country for the early establishment of highly remunerative chemical works on a large scale. To this may be added the possibility of converting the iron-residues into metal at a cost of $7.50 to $9.50 per ton, using coke in the furnace. Ducktown, with its proximity to the phosphate-beds of Alabama and South Carolina, will present the same facilities when communication by rail shall have been established.

---

## *THE INFLUENCE OF TEMPERATURE IN STEEL-MAKING ON THE BEHAVIOR OF THE INGOTS IN ROLLING.*

BY JOHN W. CABOT, BELLAIRE, OHIO.

THE fact has long been known, that the temperature at which steel is made and cast bears a very important relation to the molecular condition of the cast ingot. But until quite recently this fact has not received the consideration which its importance seems to justify. That the ingots from a very "hot" blow in the Bessemer converter, for instance, would not roll as well as those made at a lower temperature, was observed very early in the development of the process; but the further investigation of the effects of varying temperature from "hot" to "cold," has not been carried out with that degree of fulness which has been accorded to the effects on the rolling of the chemical elements, and other conditions in the manufacture.

In the following pages will be presented the results of an investigation of this subject, undertaken with the view of determining how far the influence of temperature extends, through how great a range its effects can be traced, and what temperature in the making and casting will give the best results in the rolling of the ingots.

In the series of observations forming the basis for the conclusions arrived at, while it was not possible to get the full chemical analysis of every heat considered, a complete record of each, in other details, was made, and a large number of these were averaged together to

give the figures on which the comparison was based. The observations included Bessemer rail-steel and open-hearth spring-steel.

The effect of cold pouring having been first noticed, the following record of a cold-poured heat is cited, being selected out of many such observed. A heat which had worked cold in the blowing, was allowed to remain in the vessel 20 minutes after the completion of the blow. After adding spiegel, as usual, it was poured, being so cold that it would just pour without chilling, leaving a heavy skull in the ladle. The heat worked extremely well all through, and the ingots rolled perfectly, there being no blooms requiring to be hot-chipped.

The general correspondence between the blooming and the temperature at casting, is shown by the case of three consecutive heats, one of which was made "hot," the second "medium," and the third "cold." The record shows:

| Temperature. | Rolled. | Chipped Blooms. |
|---|---|---|
| Hot, | Badly, | 8 |
| Medium, | Fairly, | 5 |
| Cold, | Well, | 4 |

The next instance presented is that of 24 consecutive heats of one day's working, the first 12 of which were made at a low heat, while the latter 12 were made at a considerably higher temperature. The average percentage of chipped blooms in the first lot was 27; by increasing the temperature about 25 per cent., the average per cent. of chipped blooms in the second lot was increased to 45.

These cases, selected from many such observed and recorded, show the bad effects on the rolling of the higher temperature at casting.

In order to become satisfied that these effects were not caused by other and accidental circumstances, and to meet the objection which might be raised, that such instances were not of sufficient number to warrant the conclusion, a much larger number of heats was taken for comparison. The temperature-records and rolling-records of four hundred heats were collected and tabulated. Of these, one hundred heats were made "hot." These were arranged together, and their average rolling-record was taken, the basis being the number of blooms in each heat requiring to be hot-chipped. One hundred heats, made at each of the points of temperature, "medium," "cool," and "cold," were treated in a similar manner. This gave four lots of rail-steel ingots, made at varying temperatures, but in other

details of the manufacture as nearly alike as it was practicable to get them, and aggregating something over 2500 tons of ingots. The averages taken on so large a scale as this, would, it was thought, eliminate accidental effects. In the absence of any known means of correctly measuring the actual temperatures of these heats, this was determined by the eye.

The averages of the four series of heats were as follows:

| Temperature. | Per cent. chipped blooms. |
|---|---|
| Hot, | 39 |
| Medium, | 34 |
| Cool, | 24 |
| Cold, | 25.5 |

The investigation was extended to the higher grades of steel, by getting the average rolling-record, as before, of two lots of open-hearth spring-steel, the first of which was made hot, the second cool. Each lot consisted of the same number of heats (amounting to about 400 tons in each), such heats only being taken for the comparison as came within certain limits as to their contents of carbon and manganese. It was thought that the influence of temperature might not be so apparent in this case as in that of Bessemer steel, owing to the fact of the lesser range of temperature obtainable in the open-hearth process, as ordinarily carried out, than in the Bessemer converter. The comparison did, however, show the same effect as that seen in the case of the Bessemer rail-steels.

The averages were:

| | |
|---|---|
| Hot heats, | 20 per cent. chipped blooms. |
| Cool heats, | 11 per cent. chipped blooms. |

In the softer grades of Bessemer steel, below rail-grade, this influence does not appear so largely. An attempt to trace it with steels of the grade of wire-rod, showed that no correspondence could be seen between the temperature and the behavior in rolling.

When we come to the still softer kinds, such as that used for nail-plates, the effect is very marked, a slight increase in the temperature of the blow above a certain maximum, producing an injurious effect on the rolling.

The foregoing experiments and observations seem to show, very strikingly, the important influence which the temperature at which steel is made exerts upon its molecular condition. This effect is injurious in proportion as the temperature increases above a certain

point; and hence it may be safe to lay it down as a general rule, that, other conditions being the same, *the colder steel is made, the better it will roll.*

The reason for this lies in the fact that the tendency to the formation of cracks in the ingot, due to unequal internal strains from excessive shrinkage, during slow solidification, is greater in steel cast at a high temperature. The different behavior in the rolls of a very hot cast ingot, and a very cold one, sustains this view. The cracks appearing in an ingot cast too hot, are few in number, large, deep and sharply defined, and are situated in the lower half of the ingot, the top generally rolling smoothly; while in the case of an ingot poured too cold, the cracking appears at the top, and has more of an irregular "red-short" character. The *bottom* of the ingot rolls smoothly, and the long, deep contraction-cracks peculiar to hot-poured steel rarely appear. The bad rolling of the tops of ingots made too cold is caused by gas-cavities, which collect near the top of the ingots. By carefully examining a section of a cold-made bloom, it will be noticed that the cracks are in reality gas-cavities, which, having been arranged about the inner surface of the shell of the ingot and perpendicular to it, have been drawn out by the rolling into short, shallow cracks, entirely different in character from the cracks characteristic of hot-made steel, which latter, remaining liquid so much longer, allows the gas to escape more fully, and leaves the upper part of the ingot free from this defect.

Now, between these two extremes, the point of temperature most favorable to the mechanical condition of the ingot is that which will reduce the cracking at each end to a minimum. This point, as indicated in the averages of heats, is that called "cool." It will be noticed that those heats made "cold," did not roll as well as those made "cool," this being due to the increased red-shortness at the top, caused, as explained above, by the imprisoned gas-bubbles.

This effect of temperature on cast-steel is seen in the case of steel castings, which, as is well known, will tear themselves apart through excessive internal strains if cast too hot.

The relation between the temperature of the liquid steel as cast, and the subsequent condition of the chemical elements in the ingot, is evidently very close. Any tendency of the elements to redistribution towards the center, or any other change, would be very much diminished, if the steel were poured at so low a temperature that it solidified rapidly.

From the chemical point of view, the relation of temperature to

the composition of steel is all-important. It is indeed the fundamental consideration in all the reactions of oxidation and reduction carried on in our steel-making and other metallurgical processes. There is a certain point of temperature for each element at which it exhibits its maximum affinity for oxygen; either above or below, this affinity is weaker. To control our oxidizing operations, as well as the chemical composition of the resulting steel, this question of temperature, as affecting the relative oxidation of the elements, must be carefully considered. Silicon, we know, oxidizes most readily at a lower temperature than carbon, iron at a higher. To get our best results, therefore, in the elimination of silicon, carbon, and manganese, in a Bessemer blow, the temperature must be so regulated that the bath will not be so hot as to prevent the last traces of silicon from oxidizing, and yet not so cold that the carbon will not all go out. It is a well-known fact, that in a very hot blow the silicon is not all taken out. If the temperature is too high, the iron is more strongly attacked, and the bath, in recarbonizing, gives off large quantities of carbon gases, and injures the quality of the steel, as is seen in the case of very soft Bessemer steel when made too hot.

Considered from both the mechanical and the chemical point of view, the question of temperatures in steel-making is one of at least as much importance as those of chemical composition and mechanical treatment.

---

## *THE STRAIGHT OR NO-BOSH BLAST FURNACE.*

(SUPPLEMENTARY PAPER.)

BY W. J. TAYLOR, CHESTER, N. J.

THE discussion on my paper entitled "Experiments with a Straight or No-bosh Furnace," read at the Philadelphia Meeting, September, 1884 (*Transactions*, vol. xiii., p. 489), suggests the propriety of supplementing it with another, giving my views as to the cause of the failure, which was so decided as to create surprise among furnace men.

As then stated, the Chester (N. J.) furnace, which had been 60 feet high, and 13 feet in diameter at the bosh, was altered to an 8-foot bosh, with a 7-foot hearth, 7-foot stock-line, and 4-foot bell,

so that, practically, the furnace was straight. The advantage I hoped to gain, was to get an active and distinct line of travel of the stock on the walls, preventing the accumulations which facilitate the carrying of partially reduced, but disintegrated ore, into the crucible, absorbing its heat, causing irregularity, high fuel, and "sharp" iron. The duration of the first blast was 16 days, and that of the second 2 days; and as the change seemed only to facilitate, instead of preventing, the formation of fine, pasty stock on the walls, the only conclusion I can come to is, that the failure was due to friction of the stock on the walls, as affected by the relation between the circumference of the shaft and its height.

We all know that furnaces do run successfully with a diameter in the largest part or bosh, of only 8 feet; but no 8-foot furnace was ever built, so far as I am aware, over 30 to 35 feet high, as against 60 feet in the case of my experiment. The new spiegel-furnaces at Newark, N. J.,—designed by Mr. E. S. Moffat—for working Franklinite or zinc residuum, are only 8-feet bosh, and 35 feet high, and work well.

In my experiment, when we allowed the stock to run down 25 or 30 feet, the furnace would become normal to all appearance; the walls would clean themselves, and the stock settle regularly (with a very light burden, however); but as soon as we filled up to anywhere near the regular stock-line, everything would become abnormal again. Under these circumstances, I can only charge the complete failure to the extreme height, as compared with the diameter; for of course the friction due to each cubic foot of stock contained in the furnace is proportionately very much greater on an 8-foot shaft than it would be on a larger one, say 10, 12, or 14 feet.

Heretofore, as we have added height to furnaces, the diameter has also been increased, and the normal conditions of the travel of the stock have been maintained. Under these circumstances, it seems probable that I had got entirely beyond the proper limits of furnace proportions, and that failure was due more to this fact than to the straight walls; and I do not now consider the experiment conclusive evidence that a straight furnace must necessarily work badly. It may be, that if we knew the law governing the relation of diameter to height, a straight furnace would be an improvement on a bosh-furnace; and the assertion in my previous paper that this experiment proved the necessity of a bosh of some kind, may, therefore, be an error.

As mentioned in the previous paper, my first design was for a

12-foot shaft, but calculations demonstrated that it would require, for economical work, 12,000 to 15,000 cubic feet of air per minute; and as the Chester furnace engine could blow only 7000 cubic feet, I reduced the diameter accordingly.

I am very much inclined to think, that had I made the shaft 12 feet, the furnace would have worked normally, even with only 7000 cubic feet of air, but not with any marked economy or advantage.

It is well known that many furnaces, after being in blast some time, cut out their boshes, and practically become straight, and yet often work well. In other cases furnaces require straight sides (and are made quite small, too), through scaffolds, which often reduce the diameter to much less than 8 feet. The Chester furnace has been run with a ring-scaffold that reduced the size of the upper part, for more than 20 feet, to 4 to 6 feet in diameter; and it worked quite regularly, but only made an output of about 150 tons per week, on a very high fuel-consumption (say $1\frac{3}{4}$ tons of fuel to 1 ton of metal). In this case, however, the lower part of the furnace was full-sized, the scaffold beginning about 10 feet above the tuyeres.

In conclusion, I would add, that after abandoning the straight furnace we left the hearth and tuyeres unaltered, and gave the bosh an angle of 80°, beginning at the tuyeres, which brought the top of the bosh (13 feet in diameter) 17 feet above the tuyeres, then drew in to $8\frac{1}{2}$ feet at the stock-line, put in a 5-feet bell—and the furnace is now working well, making an output averaging nearly 300 tons per week, on the same ores as before, and with a fuel-consumption of less than $1\frac{1}{4}$ tons per ton of iron.

In view of the wide range of lines and dimensions on which furnaces have been constructed and more or less successfully run, as illustrated by Mr. Birkinbine, in the discussion following my previous paper, it seems strange that a change so slight as this should make the extreme difference between a complete failure and a marked success.

---

## *EXPERIMENTS WITH BOLTS AND SCREW-THREADS.*

BY MAJOR WILLIAM R. KING, U. S. ENGINEERS, CHATTANOOGA, TENN.

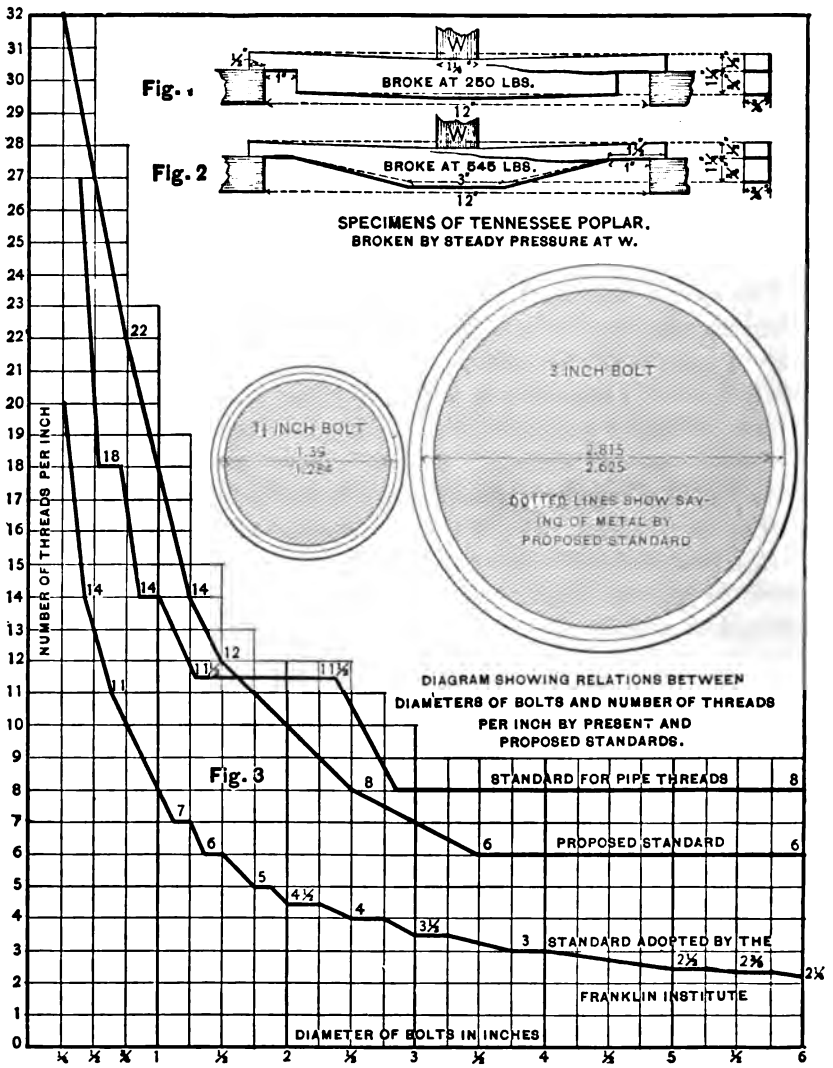
My attention was drawn to this subject just twenty years ago this month, when I was detailed to rebuild one of the bridges in Richmond that had been burned during the evacuation. We took pos-

session of the Tredegar Iron Works, rolled the iron for the bolts and rods, made castings from old shell and other scrap, borrowed the necessary timber from the remains of the navy-yard, and rebuilt Mayo's Bridge, 1400 feet long, in about six weeks, the soldiers doing most of the work. Although I had taken special pains in proportioning the bridge, and had introduced what Holley has designated as a suitable "factor of ignorance," I was not at all satisfied of the stability of the bridge when completed, on account of the evident weakening of the principal rods by cutting coarse "standard" threads upon them, and I was greatly relieved of anxiety when a few years later an unprecedented flood in the James River picked up that bridge and carried it bodily out upon the bosom of Chesapeake Bay.

The matter was again forcibly suggested a few years later, when I was investigating the subject of armor-plating. I found that bolts were a great source of weakness, and, as a general rule, especially in all the earlier experiments, when any of the armored targets were struck by heavy projectiles, the result was a perfect hailstorm of bolt-ends, nuts and washers. In fact, it may almost be stated as a rule, that in all similar engineering work the bolts are the weakest part of the structure. This is perhaps due to the fact that we almost always look at the side rather than at the end of a bolt, which makes about 30 per cent. difference in the *apparent* strength. In order to strengthen a chain we must strengthen the weakest link, and as cutting away too much metal for the screw-thread weakens bolts, which in turn are themselves sources of weakness, it is evident that we must begin at the thread. If the thread is cut deeper than is required to prevent stripping, it must weaken the bolt and in a most insidious way, for it is the very method taken by the blacksmith to break iron or steel bars; and it should be noted right here that the standard thread is cut much deeper than the blacksmith nicks his bars.

Without going into the mathematical work by which the facts were proved, it may be stated that, in connection with the armor-plate investigations already referred to, I found theoretically: first, that with a perfect-fitting thread it makes no difference in regard to the strength of a bolt-thread how fine it is made, since the length of thread increases just as fast as its strength of cross-section diminishes; second, that with such a thread one-fifth of the diameter of the bolt is a sufficient thickness of nut to prevent stripping; third, that about one-fifth the cross-section of the bolt would be a sufficient

cross-section of nut to prevent bursting. These dimensions are very far within the limits to which any one would think of carrying the reform, but they indicate that there is a very broad margin between existing practice and safe economy.




The advantage of having every part of a structure of a strength proportional to the strain upon it is not generally appreciated. The "Deacon's One-horse Shay" was more of a reality than is generally understood. *A beam may be actually strengthened by cutting away*

*portions of it.* Figs. 1 and 2 represent two little wooden beams, for example, that show how the strength of a beam may be more than doubled by cutting away surplus timber, and leaving all parts strong in proportion to the strain they are required to resist. The same principle applies to bolts.

But in such matters actual experiment is the safest—if not the only safe—guide; and fortunately such evidence is available. The following account of one set of experiments is from my last annual report, made in July of last year:

"EXPERIMENTS WITH SCREW-THREADS AND NUTS.

"Having occasion to use a large number of screw-bolts in building iron-lock gates for the Muscle Shoals Canal, my attention was again directed to the proper proportions of threads and nuts. About fourteen years ago, while experimenting with materials for armor-plating, I became convinced that the 'standard' sizes for V-shaped threads were very much too coarse for nearly all purposes, and that the size of nuts was out of all proportion to the strains upon them, since the bolts themselves would invariably break long before the thread or nut would yield. These facts were briefly set forth in 'Professional Papers, No. 17,' printed in 1870, and the practical tests now made have fully verified the conclusion then reached. Four test-bolts were made. They were all from the same quality of wrought-iron, and were forged at the same time. The shanks of the bolts were turned and the heads and nuts were faced up in the usual way, the outside of heads and nuts being left in a rough state. No special care was taken in fitting the nuts. Two of these bolts had the standard threads of six to the inch, and two had twelve to the inch, and all the heads and nuts were made about two sizes lighter than the tables prescribe for 1½-inch bolts. As the fine thread weakens the bolt much less than the coarse one, and must be proportionately stronger, the principal questions to be settled were whether the thread of the fine-cut bolts would strip or the head or nut would give way before the bolt itself would break.

"These questions were definitely settled by having the bolts carefully tested on the government testing-machine at the Watertown Arsenal, which was done by the courtesy of Major F. H. Parker, United States Ordnance Corps.

"There was no sign of stripping the thread or bursting the nut in any case, and the coarse threads broke at an average strain of 66,325 pounds, while the fine ones stood 78,400 pounds, or over

18½ per cent. more. The fracture in every case was at the bottom of a thread, as usual, but the fine-threaded bolts were elongated 4⅓ per cent. of their length, while the coarse ones were only stretched 2 per cent., which shows that the 'work' of breaking the former was more than 2½ times as great as in the case of the 'standard' bolts. The tensile strength of the iron was found to be 59,785 pounds per square inch of original section in the coarse-threaded bolts, and 58,495 pounds in the fine ones, showing that the experiments, if anything, slightly favored the standard bolts, and that the results are due entirely to the fact that the coarse threads cut away too much metal; and it is quite probable that even finer threads than those tested, say 16 or 18 to the inch, would give better results.

"The importance of the results is evident from the fact that a net increase of about 20 per cent. in the statical strength of bolts and 150 per cent. in their resistance to sudden strains can be made by simply using finer threads, and at least 40 per cent. of the iron in the head and nut can be saved by making them that much lighter. It is certainly a mystery why manufacturers will persist in throwing away metal and labor in making coarse threads which cut away the bolts unnecessarily at their weakest point, and I can only account for it upon the theory that the present scales have been inherited from the coarse blacksmith work of former years, which has been carried into our modern and more refined practice to avoid changing taps and dies. . . . . ."

It should be stated that the outside of the thread in all these bolts was $\frac{1}{16}$ inch smaller than the body of the bolt, or the latter would have shown greater elongation.

To test the matter still further, I have recently had three more pairs of bolts made, one pair having 6 threads, one 12 threads, and one pair 18 threads to the inch; but in all other respects the bolts were as nearly alike as it was possible to make them. They were turned from bar iron 1⅝ x 2 inches square, so that no forging was required.

The results were still more favorable for the fine thread, for when broken in a hydrostatic press not a single nut showed signs of weakness, and the bolts with 18 threads to the inch showed unmistakably that they were stronger than the others, although they finally yielded by pulling out of the nut—not by stripping the threads, as we generally understand it, but by actually drawing down the size of the bolt until the greater part of the threads were disengaged, as can be seen from the specimens.

In Fig. 4 I have plotted the strains and corresponding stretch of

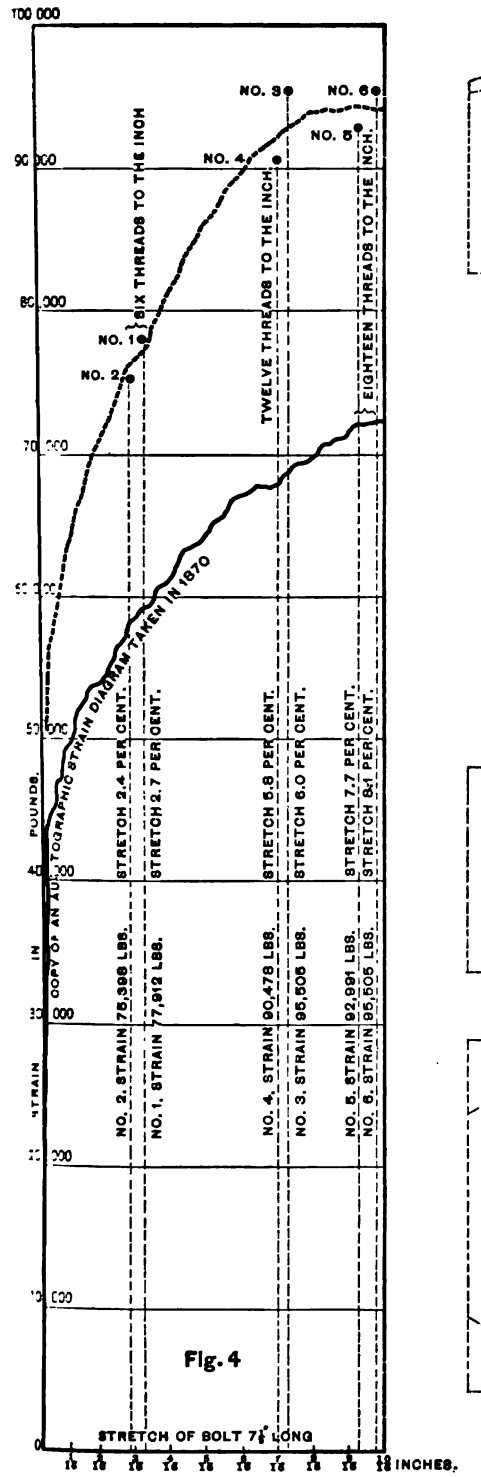

100 000
90 000
80 000
70 000
50 000
40 000
30 000
20 000
10 000
0
POUNDS.
STRAIN IN
NO. 3
NO. 6
NO. 5
NO. 4
NO. 1
NO. 2
SIX THREADS TO THE INCH
TWELVE THREADS TO THE INCH
EIGHTEEN THREADS TO THE INCH
COPY OF AN AUTOGRAPHIC STRAIN DIAGRAM TAKEN IN 1870
STRETCH 2.4 PER CENT.
STRETCH 2.7 PER CENT.
STRETCH 5.8 PER CENT.
STRETCH 6.0 PER CENT.
STRETCH 7.7 PER CENT.
STRETCH 8.1 PER CENT.
NO. 2. STRAIN 75,398 LBS.
NO. 1. STRAIN 77,912 LBS.
NO. 4. STRAIN 90,478 LBS.
NO. 3. STRAIN 95,506 LBS.
NO. 5. STRAIN 92,991 LBS.
NO. 6. STRAIN 95,505 LBS.
STRETCH OF BOLT 7½ LONG
INCHES.

Fig. 4

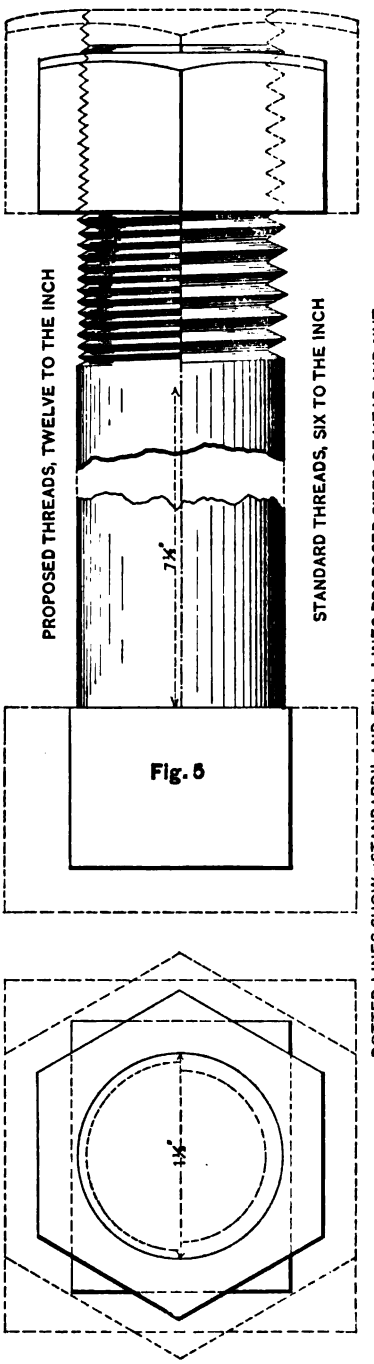

PROPOSED THREADS, TWELVE TO THE INCH
STANDARD THREADS, SIX TO THE INCH
7½"
1½"
DOTTED LINES SHOW "STANDARD," AND FULL LINES PROPOSED SIZES OF HEAD AND NUT

Fig. 5

the six bolts, and, for comparison therewith, a diagram enlarged from an autographic sheet (similar to an indicator-diagram), taken in 1870, which is thought to be the first attempt ever made to get a continuous record of the behavior of iron under varying strains.

| | Pounds. |
|---|---|
| The standard bolts broke at an average strain of, . . . | 76,655 |
| Those with 12 threads at, . . . . . | 92,991 |
| Those with 18 threads yielded at, . . . . . | 94,248 |

It will be noticed that the latter were just on the point of breaking when the nut pulled off.

*Mean Results.*

| | 6 threads. | 12 threads. | 18 threads. |
|---|---|---|---|
| Relative tensile strength, . . . | 1 | 1.21 | 1.23 |
| Stretch, . . . . . | .025 | .06 | .08 |
| Relative work, . . . . . | .025 | .0726 | .0984 |
| Or, . . . . . | 1 | 2.9 | 4 |

Fig. 5 shows comparative views and sections of the six-thread and twelve-thread bolts. The advantages sought by increasing the number of threads per inch are:

1. At least 20 per cent. additional statical strength.
2. Three or four times the strength to resist impact.
3. The finer threads are easier to cut.
4. They are less liable to work loose.
5. In many cases this practice will take the place of upset or enlarged bolt-ends.
6. In such cases it would have the advantage of filling the hole, or, rather, it would avoid the necessity of making the holes larger than the body of the bolts.
7. There will be a saving of 50 or 60 per cent. in weight of heads and nuts; also in cost.
8. Bolts may be placed closer to angles in structures without chipping out for head or nut.

The disadvantages would be:

1. Cost of changing taps and dies.
2. Additional time required to put on or remove nuts, which, of course, is hardly worthy of notice.
3. In case of bolts frequently removed there would, of course, be a greater loss in strength from wear and rust of surfaces of thread.

We have seen, however, that this wear must go on until the No. 12 thread is as fine as the No. 18 thread before the nut will strip. In some cases, like the bolts that secure the cylinder-heads of a steam-engine, it will probably be best to retain a coarse thread.

The great excess of strength in the ordinary screw-thread is evident from the experience with French breech-loading guns, where the enormous strain due to the explosion of the charge is held by only a fraction (considerably less than one-half) of the threads, the balance being either cut away or not engaged. In a 16-inch rifle, *e. g.*, the strain on the breech-plug is about 4000 tons.

Although the cost of changing to the proposed system would be very great, I believe the country could well afford to buy up all the old taps and dies at their weight in standard silver dollars and destroy them, just as they do obsolete dies at the mints.

Some might think it best to wait for the adoption of the metrical system before taking action in this matter, as another change would, of course, be necessary in that event; but I think this would be a mistake. The metrical system is making very slow progress in this country, and its practical use would reach everybody and send them back to their school-books, while this change would simply affect manufacturers of machinery, etc., and only require changes in tables, gauges, and other special tools.

If any reliable person should claim that he had discovered a method of saving 10 per cent. in the cost of producing pig-iron, it would arrest the attention of the entire pig-iron community; but I doubt very much whether a positive demonstration, both theoretical and experimental, that a saving of 20 to 60 per cent. can be made in the cost of more highly wrought or finished work, like bolts and nuts, will attract enough attention to secure even a fair investigation of its merits. I should feel more hesitation in advocating a reform of so ancient and conservative an institution as the standard of bolts and screw-threads if it were not for the fact that the world is full of just such antiquated humbugs. Take the Birmingham wire-gauge for example, or our system of weights and measures, with two or three different pounds and tons, and no system whatever in fixing the ratios between units of different orders.

The standard for threads, which I have indicated by a broken line (see Fig. 3), with a diagram of pipe-threads and the Franklin Institute Standard, is merely suggested for consideration, and, of course, should not be adopted without careful experiment with all sizes of bolts, to see that the figures given are those best suited for

each bolt. I have endeavored, without attempting any great nicety, to fix upon the simplest combinations of numbers that will give about double the standard number of threads to the inch and avoid fractional numbers of threads, so far as possible.

Instead of introducing such complications as $2\frac{7}{8}$ or $2\frac{5}{8}$ threads to the inch, I would suggest that whole numbers be fixed for each $\frac{1}{4}$ inch of bolt diameter, and then let each of the intermediate sizes of bolts have the same number of threads as the bolt next below it in size.

---

## *TREATMENT OF ROASTED PYRITES BY THE LONGMAID AND CLAUDET PROCESSES FOR THE EXTRACTION OF GOLD AND SILVER.*

BY T. EGLESTON, PH.D., NEW YORK CITY.

THE treatment of the residues from the manufacture of sulphuric acid which contain small amounts of copper, silver and gold, has attracted considerable attention in Europe. They are successfully treated in several works on the continent, and in as many as twenty establishments in different parts of England. As the process must sooner or later attract attention in this country, I have put together my notes made in three of the most important establishments in Europe. These are the works at Hemixem near Antwerp, of Duisbourg in Westphalia, and of Oker in the Hartz. In the last works only, the ores are produced in the vicinity of the place where they are treated.

The works at Duisbourg treat ores which come from the Rio Tinto mines in Spain, which often contain considerable quantities of arsenic. They are roasted in a number of different works along the Rhine for the manufacture of sulphuric acid. They are brought by boat and are landed at the works by steam-cranes. They are carried at once by a double-inclined plane worked by steam to the storage-houses to be kept until treated. The wagons, after being weighed, are dumped. The ore is assayed at once, the assay-sample being taken from the boat while the ores are being discharged. They are all fine, and contain two to eight per cent. of copper and about sixty per cent. of iron, and a small amount of silver and gold.

Their average composition is given below:

| | |
|---|---|
| Iron, | 58.25 |
| Zinc, | 0.37 |
| Lead, | 1.14 |
| Copper, | 4.14 |
| Arsenic, | 0.25 |
| Sulphur, | 3.76 |
| Lime, | 0.25 |
| Oxygen, | 26.93 |
| Water, | 3.85 |
| | 98.94 |

The works at Hemixem near Antwerp treat an ore from Vigsnaes, in Norway, which has been roasted for the manufacture of sulphur, in a number of chemical establishments on the Rhine, and is sent to the works by canal. It is discharged by two steam-cranes and carried to large piles in the works. The ore is of different sizes, and comes to the works in lump, grains, and dust which have been treated for different purposes, and which contain different quantities of sulphur. They contain on an average:

| | Lumps. | Grains. | Dust. |
|---|---|---|---|
| Copper, | 5 to 9 per ct., | 3.5 to 5 per ct., | 2.8 to 3.5 per ct. |
| Sulphur, | 5 to 8 " | 5 to 7 " | 3 to 3.5 " |

The average of all the ores is copper 5.5 per cent. and sulphur 6 per cent.

Inside the works the ore is weighed, and then dumped by means of a steam-crane into large piles, the ore being classified by locality and by richness. It was formerly dumped into large storehouses covered with a roof and protected with strong brick walls. As the ore is wet when it arrives, the pressure from the decomposition has been sufficient to endanger the houses, so that now the ore-heaps have a roof over them, but have walls only one meter high on the sides.

The ore in lumps is crushed in a pair of Cornish rolls, and then with the other ore is classified and sized on screens so arranged that the ore which does not pass them goes back to the rolls. It is then weighed, sampled, and assayed. The ores at Oker are ordinary copper-ores which have been roasted at the works to produce the sulphuric acid, the mother-liquors of which are used in the separation of the silver from granulated black-copper.* They contain, when roasted, from 7 to 10 per cent. of copper, and 6 to 8 per cent. of sulphur (combined for the most part with iron); from 35 to 40 per cent. of iron, about 2 per cent. each of lead and zinc, and

* *Production of Gold and Silver in U. S.* Burchard. 1884.

from 0.008 to 0.01 per cent. of silver. As they have been already treated for sulphuric acid, these are crushed and ready for further treatment. The ore is sized on screens with meshes from two to four millimeters square. Experience has shown that this is the best size. If it is finer, it will not filter well; if it is coarser, it may not be sufficiently roasted.

The process by which these ores are treated varies in its details, but is essentially the same in all the works. It consists of seven different phases:

1. Mixing the ore with salt.
2. Roasting the ore.
   *a.* Absorption of the furnace gases.
3. Leaching the ore.
   *a.* Leaching with the mother-liquors.
   *b.* Leaching with the acid water of the coke-towers.
   *c.* Treatment of the residues.
4. Precipitation of the gold and silver by the Claudet process.
5. Precipitation of the copper.
6. Treatment of the cement-copper.
7. Fining and refining the cement-copper.

Most of the iron, zinc, nickel, cobalt, lead and copper are in the state of oxides; the roasting transforms these as well as the silver and gold into chlorides, which are very easily soluble in the acid mother-liquors from which the copper has been precipitated. A small part of the copper remains as oxide which is dissolved out in the acid waters. There should always be from $\frac{3}{4}$ to 1 per cent. more sulphur than copper in the ore. If from any cause there should not be sufficient sulphur to efficiently carry out the roasting, this is added in the shape of iron pyrites. The amount of salt required to be added will vary from 15 to 20 per cent. of the weight of the ore. The silver and gold in solution are precipitated together, and the copper by itself, while the residues, after these metals have been dissolved out, are valuable products easily sold or used in the works.

### 1. *Mixing the Ore with Salt.*

At Duisbourg the proper quantity of salt having been first ascertained, is measured in wooden boxes, and is thrown through a grating upon the ore. It is then passed through a set of Cornish rolls to reduce it to the size of about a millimeter cube. It is thus thoroughly mixed. From the rolls the ore falls on a series of sieves, and what does not pass is carried back to the rolls.

When the ore is mixed and sized, it is carried to the roasting furnaces by an endless chain. At Hemixem the ore, according to its size, is ground in two different sets of Cornish rolls, the products of which are separated by screens, and carried by endless chains either back to the rolls or to the store-house for the ground ore, where the proper quantity of salt is added to it. This will be, on an average, 20 per cent., but if the ores contain above 5.5 per cent. of copper it may be as high as 35 per cent. The ore and salt are charged into a hopper from a wagon running on rails over the top of it, and arranged with a bottom movable by an outside lever. The quantity put into the wagon is weighed, so that the charge in the hopper is always the same. The hopper connects by a pipe with a cast-iron drum made of two frustrums of cones put together by their bases, on which a gear-wheel is fitted. This is attached by a pinion so that it can be made to revolve very rapidly. The ore and salt together are discharged by a slide-valve in the bottom of the hopper into a vertical pipe on one of the sides of the drum, and discharged from its opposite side into a wagon by an Archimedes screw working in the discharge pipe. The drum is made to revolve very rapidly, and as the only outlet is from the pipe opposite to the charging-side, the mixture is made so rapidly and perfectly that it is discharged every two to three minutes. The machine receives a charge of 700 kilos, and as the work is so rapid, the charging-side is arranged as a bin which is always filled with a new charge as soon as a charge has been made in the drum. The greatest advantage has been found in the use of this mixer, both in saving salt and in insuring the most economical use of that which is mixed with the ore. It is doubtful whether this special machine answers any better than the methods used in the West.* In order to avoid the dust, it is necessary to have the ore a little moist. Two mixers can prepare 45 to 50 tons in a day.

At Oker the mixture is made in an edge-mill, of which there are two, in which the pan alone is actuated. Each mill treats 34 tons of the mixture of ore with 15 per cent. of the Stassfurt potassium-chloride salts per day, with one man tending, grinding the mixture to the size of $2^{mm}$. There is no disadvantage in making the mixture faster than it can be used. It has been found by experience that a certain amount of chlorides are formed both before and after † the material leaves the furnace, so that there is a gain in keeping it in heaps for even five or six weeks beyond the time necessary to provide for accidents to the mixer.

* *Transactions*, vol. xii., p. 46.

† *Transactions*, vol. xii., p. 48.

### 2. *Roasting the Ore.*

The mixed ground ores are roasted in reverberatory or muffle-furnaces to form chloride of copper. The temperature during this operation must never be above dull red, and must not be continued after the assay shows that most of the copper has been transformed into $CuCl_2$, as this compound is liable to be decomposed at a high temperature, losing its chlorine and forming $Cu_2Cl_2$, which seriously interferes with the precipitation of the silver; besides which the chlorides are volatile at a higher temperature, and oxychlorides are liable to form, which are wholly or partly insoluble and very difficult to treat. The ore should not contain, to secure the proper reactions, less than 0.75 to 1.5 per cent. of sulphur for every per cent. of copper.

As the amount of material to be transported is large and there are large quantities of liquid to be moved, the works, with the exception of those at Duisbourg, are all arranged in terraces, so that the material is moved as much as possible by gravity. The works at Duisbourg are situated in a perfectly level country, so that all the spent material has to be often handled, and the construction of the works is rendered much more complicated than it otherwise would be.

The roasting is done on the highest level in furnaces of different sizes, with the admixture of from 8 to 10 per cent. of salt. Great stress is laid in the works on this incorporation of salt with the ore.* At Duisbourg there are ten roasting furnaces, all of them being muffles, as the gases are collected to make soda-cake. In six of these furnaces the hearth is $9^m$ long by $4^m$ wide inside. The fire-place is $3^m$ wide by $1.20^m$ long. They treat a charge of 2250 kilos. The four larger furnaces have a hearth $10^m$ long by $5.50^m$ wide, inside, and treat a charge of 2700 kilos. The depth of the charge spread out over the hearth is from $0.05^m$ to $0.08^m$. It is left spread out to be heated for one and a half hours. It is then rabbled every half hour for six or eight hours. Toward the last, assays are made to ascertain the progress of the work, and when the assay shows that it is finished, the ore, still containing from one-half to one per cent. of sulphur, is raked through a hole inside the furnace into cubs on the outside, there being one before each door. These are covered with an iron plate with a handle, and can easily be removed. Two men per furnace only are required to charge, rabble and discharge the ore and carry it to the cooling-floors, where it is spread out in beds of $0.30^m$ in thickness and left twenty-four hours to cool.

* *Transactions*, vol. xii., p. 46.

At Hemixem the ore is carried from the mixer in an iron wagon directly to the muffle-furnaces. There are eight of these furnaces, which are 13$^{m}$ long, 5$^{m}$ wide and 2$^{m}$ high on the outside. They have seven working doors on a side and three charging holes on the top. The height of the muffle is one meter. Each hearth has 40 square meters of working surface. A railroad runs over the top. The cars discharge into cones over the three charging-holes which spread it out over the top of the furnace where it remains from 3 to 4 hours to dry. The charge is five tons for each furnace, which takes from twenty to twenty-five minutes to make. It remains an hour to be heated up and is then rabbled every half hour, the whole operation lasting six hours. Four charges are made in 24 hours. The amount of fuel burned in each furnace in that time is 1550 kilos, or 77½ kilos per ton of ore. The temperature of the furnace is about 500° C. near the fire-place, about 400° at the flue. In these furnaces 140 tons a day can be treated.

The charge in all of the works is drawn into cubs, and after remaining there for two hours is carried to the paved cooling-floor in iron barrows, where it is spread out in a bed .30 to .60$^{m}$ thick, and left 24 hours to cool. Two men do all the work of one furnace, charge and discharge the ore, and, besides, carry it to the cooling-floor.

At Oker there are three muffle-furnaces heated with producer-gases. These are 8.75$^{m}$ by 3.50$^{m}$ and 1.75$^{m}$ on the outside. The height of the muffle in the centre of the arch is 0.68$^{m}$. The gas is conducted under the hearth through five flues. The bottom of the hearth is made of bricks which lap on the walls which separate the flues. The furnace has four working-doors on each side and four hoppers for charging on top, corresponding to the working-doors on each side. The hoppers are closed by a cast-iron damper with a handle, which is raised to let the ore in and covered with ore during the roasting to make it gas-tight. The ore is brought in an iron tip-wagon running on rails over each of the hoppers. The charge of ore is five tons. It is left in the furnace for four hours until it is dull-red. It is then rabbled for five hours with inlet of air. In ten hours the charge is finished, so that only two charges or ten tons can be treated in 24 hours.

The general experience is in favor of muffle-furnaces. They not only give a heat more uniformly distributed, but as the gases are forced to remain a certain time in the furnace, the ore is more perfectly chlorurized, besides which they give purer acid liquors which are to be used in the treatment. This more than compensates for the extra fuel which they use.

In all the works, frequent assays are made toward the end of the roasting, to ascertain exactly the condition of the copper. It is considered finished when about 75 per cent. of the copper is soluble in water, which will be in the state of chloride, 20 per cent. in dilute acid, which will be in the state of an oxide, and 5 per cent. insoluble in dilute acid, in the shape of sulphides.

In order that the roasting should be properly done, the copper in the original charge must be for the most part as oxide, and there must be sulphur enough present as bisulphide, not as subsulphides, to insure the formation of sulphides whose decomposition causes the formation of the nascent chlorine, which attacks the metals present, even the gold. The presence of any considerable quantity of subsulphides is not favorable to a complete attack of the oxides.

Bräuning* gives the following analyses of two samples from Oker, taken in the middle and at the end of the roasting. The analysis at the former stage is as follows:

SOLUBLE IN WATER.

| | | | | | |
|---|---|---|---|---|---|
| Cu | 1.94 | calculated as | CuCl, . . . . | 3.11 | per cent. |
| Ag | 0.003 | " | AgCl, . . . . | 0.004 | " |
| Fe | 0.74 | " | FeCl, . . . . | 1.68 | " |
| $Al_2O_3$ | 0.12 | " | $Al_2O_3 3SO_3$, . . . | 0.39 | " |
| Mn | 0.69 | " | MnCl, . . . . | 1.58 | " |
| Ni | 0.20 | " | NiCl, . . . . | 0.44 | " |
| Zn | 1.60 | " | ZnCl, . . . . | 3.40 | " |
| CaO | 2.76 | " | CaCl, . . . . | 6.27 | " |
| MgO, KO, NaO | | as sulphates from chlorides, . . . | | 18.15 | " |
| | | | | 35.024 | " |

INSOLUBLE IN WATER.

| | | | | | |
|---|---|---|---|---|---|
| Cu | 4.32 | calculated as | $CuO$, . . . . | 5.12 | per cent.† |
| | | | $Cu_2S$, . . . . | 0.29 | " ‡ |
| Pb | 0.39 | " | $PbOSO_3$, . . . | 0.57 | " |
| Fe | 34.49 | " | $Fe_2O_3$, . . . | 45.38 | " |
| | | | $Fe_2O_3SO_3$, . . . | 3.27 | " |
| | | | $FeS_2$, . . . . | 2.64 | " |
| $Al_2O_3$ | 3.30 | " | $Al_2O_3$. . . . | 3 30 | " |
| Mn | 0.03 | " | $Mn_2O_3$. . . . | 0.04 | " |
| Zn + Ni | 0.29 | " | ZnO + NiO, . . | 0.36 | " |
| CaO | 0.45 | " | $CaOSO_3$, . . . | 1.09 | " |
| $SO_3$ | 1.86 | | | | |
| S | 1.47 | | | | |
| Cl | trace | | | | |
| Insoluble in acid, . . . . . | | | | 2.93 | " |
| | | | | 65.02 | |

* *Zeit. für Berg-, Hütten-, u. Salinenwesen*, vol. xxv., p. 159.

† Soluble in muriatic acid. ‡ Soluble in aqua regia.

More than half the copper is insoluble.

The second analysis of a sample taken at the end of the roasting is as follows: *

SOLUBLE IN WATER.

| | | | | |
|---|---|---|---|---|
| Cu | 3.86 | calculated as | CuCl, . . . . | 8.17 per cent. |
| Ag | 0.005 | " | AgCl, . . . . | 0.006 " |
| Fe | 0.60 | " | FeCl, . . . . | 1.38 " |
| $Al_2O_3$ | 0.17 | " | $Al_2O_3 3SO_3$, . . . | 0.56 " |
| Zn | 1.64 | " | ZnCl, . . . . | 3.42 " |
| Mn | 0.75 | " | MnCl, . . . . | 1.71 " |
| Ni | 0.07 | " | NiCl, . . . . | 0.15 " |
| CaO | 1.60 | " | CaCl, . . . . | 3 17 " |
| MgO, KO, NaO | | as sulphates from chlorides, | . . . . | 20.50 " |
| | | | | 39.066 " |

INSOLUBLE IN WATER.

| | | | | |
|---|---|---|---|---|
| Cu | 2.57 | calculated as | CuO, . . . | 3.18 per cent. |
| | | | $Cu_2S$, . . . | 0.03 " |
| Pb | 1.17 | " | $PbOSO_3$, . . . | 1.26 " |
| Fe | 34.56 | " | $Fe_2O_3$, . . . | 47.91 " |
| | | | $Fe_2O_3SO_3$, . . | 1.02 " |
| | | | $FeS_2$, . . . | 1.18 " |
| $Al_2O_3$ | 0.44 | " | $Al_2O_3$, . . . | 0.44 " |
| Zn | 0.37 | " | ZnO, . . . | 0.46 " |
| Mn + Ni | trace | | | |
| CaO | 0.49 | " | $CaOSO_3$, . . . | 1.19 " |
| $SO_3$ | 1.49 | | | |
| Cl | trace | | | |
| S | 0.64 | | | |
| Insoluble in acid, | | | | 3.69 " |
| | | | | 60.36 |

This sample shows so small a portion of the copper insoluble that it can be treated, while most of the silver and nearly all the gold are in the state of chloride.

*a. Absorption of the Furnace-Gases.*—At Duisbourg the gases pass up tubes filled with coke about $0.50^m$ in diameter, and descend tubes about $0.20^m$ in diameter to go to the furnace. As they are near the city, large quantities of water are used to prevent any escape of the acid gases. This is all collected to be used in the second leaching. The small tubes from which the acid runs often get choked with oxide of iron, and must be cleaned frequently. As the gases which escape from the furnaces contain both acid and volatilized

* *Ibid.*, p. 160.

chlorides, they must be condensed. This is done in towers in which fire-brick or coke is loosely piled.

At Hemixem there are three such towers. They are three meters square, and from 17 to 21 meters high. The acid waters at 6.5° B. On a level with their tops are three long tanks for the water supply of the whole works.

At Oker there are two such towers 1.5$^{m}$ square and 5.5$^{m}$ high. The acid waters from these coke towers are very weak, not over 1° to 1.5° B.

### 3. *Leaching the Ore.*

The ore on the cooling-floor when it has become cold is sampled and assayed. It will generally average from three to eight per cent. of copper and two to three per cent. of sulphur, which last is present mostly as insoluble sulphides. It is then ready for leaching. This is done in lead-lined vats, the wood-work of which is painted on the outside with tar. They are all made on the same general plan, differing only in slight details of construction. At the bottom of each vat on the outside there are launders, generally hollowed out of sticks of hard pine, to carry the outflowing liquors to their proper places, so that any vat can, when necessary, be cut out of the circuit.

At Duisbourg there are 16 vats 4$^{m}$ long by 3.5$^{m}$ wide and 1.25$^{m}$ deep. At Hemixem there are 20, 6$^{m}$ long and 3$^{m}$ wide and 1.15$^{m}$ deep. At Oker there are 16, 3$^{m}$ square and 1.30$^{m}$ deep.

The false bottom of each of these vats is made of slats of wood over which straw is placed to form a filter. This is covered with some spent ore so that the total height of the filter is 0.20$^{m}$. Between the two bottoms there are three holes closed with plugs for drawing off the liquors. At Duisbourg the vats are charged with twenty tons of the calcined ore. At Hemixem the charge is twenty-five tons; at Oker it is ten tons.

The roasted material contains $CuCl_2$, and some of the iron chlorides soluble in water, all of the gold and silver, and part of the oxide of copper, as well as part of the $Cu_2Cl_2$ which is soluble in the chlorides of sodium and of iron. The rest of the $Cu_2Cl_2$ and of the oxide of copper is soluble in the condensed acid liquors.

*a. Leaching with the Mother-Liquors.*—The ore is first leached with the mother-liquors from the precipitation-tanks. These are collected at Hemixem in a series of vats in the open air where they are stored. In these vats branches of trees are placed, in order that a certain amount of the salts of soda and lime which they contain may crystal-

lize out. When they have remained a sufficiently long time, they are pumped up to the point required by injectors. The composition of this mother-liquor at Oker is given by Bräuning as follows:*

100 parts of the mother-liquor, spec. grav. 1.145 = 18° B., contain,

| | |
|---|---|
| Cu, | 0.015 |
| Pb, | trace |
| FeO, | 2.14 |
| $Fe_2O_3$, | 0.15 |
| $Al_2O_3$, | 0.11 |
| ZnO, | 0.06 |
| MnO, | 0.31 |
| CoO + NiO, | 0.01 |
| CaO, | 0.12 |
| MgO, | 0.52 |
| Alkalies, | 2.61 |
| Cl, | 2.56 |
| $SO_3$, | 5.89 |
| As + Sb, | trace |
| Total solids, | 14.495 |

There are slight variations in the method of conducting this operation. At Duisbourg, only the waters of condensation heated to boiling are used in this first washing. The rich liquors are treated, while the poor ones are stored to be used over again on fresh quantities of ore. At Hemixem, the ore is allowed to slowly absorb all that it will take until it is covered ten to fifteen centimeters deep. This is allowed to remain for a longer or shorter period, depending on previous experience with the ore. The plugs are then removed, and the liquid allowed to drain off. This generally takes from twenty-four to twenty-seven hours. At Oker, the mother-liquor is turned on to the vat, and as soon as the ore is saturated with it, the plugs are removed from the bottom, and the liquid is allowed to run out, and fresh liquid to run in, as long as the liquor remains blue. When it ceases to be so, the mother-liquor is cut off and allowed to drain for a short time. As the mother-liquor comes in contact with the ore, the absorption of the anhydrous salts contained in it causes such a rise in temperature that it is brought up nearly to the boiling-point. The composition of the liquor is given by Bräuning as follows:†

* *Zeit. für Berg-, Hütten-, u. Salinenwesen*, vol. xxv., p. 161.

† *Ibid.*, p. 161.

100 parts of the mother-liquor, spec. grav. 1.355 = 38° B., contain,

| | |
|---|---|
| Cu, | 3.71 |
| Pb, | 0.01 |
| Ag, | 0.005 |
| Bi, | trace |
| $Fe_2O_3 + Al_2O_3$, | 0 29 |
| ZnO, | 4.97 |
| MnO, | 0.58 |
| CoO + NiO, | 0.04 |
| CaO, | trace |
| MgO, | 0.27 |
| Alkalies, | 10.60 |
| Cl, | 12.56 |
| $SO_3$, | 8.95 |
| As + Sb, | 0.32 |
| | 42.305 |

This solution, heated to 40° B., is turned on to the ore, its flow being regulated by a stopcock. A comparatively small quantity of the copper, but nearly the whole of the precious metals, have been dissolved; hence these liquors are kept by themselves. This first leaching at Oker takes from five to six hours, sometimes a little less, sometimes more, according to the ore that is treated. In some of the works each charge of liquor on the ore is called a washing, and as many as nine of them are made. The first two, owing to the large excess of salt, dissolve from 75 to 80 per cent. of all the silver, and almost the whole of the gold. The third dissolves less than 20 per cent., and the remainder is scattered through the other six, the quantity rapidly decreasing. The first three of these washings only, as they contain about 95 per cent. of the silver, are treated at once. The last six are considered as poor liquors, and are treated for copper.

*b. Leaching with the Acid Water of the Coke-Towers.*—The ore is then leached with the acidulated water coming from the condensation of the furnace-gases in the coke-towers brought up to the boiling-point with steam, and strengthened with additional muriatic acid. The object is to leach out the remaining chlorides and oxychlorides.

At Oker a third leaching is done with hot water to which sulphuric acid has been added, so as to bring it up to 8° B. This is allowed to remain for forty-eight hours, or until the liquor is neutral. The analysis of the liquor after that time is, according to Bräuning:*

* *Ibid.*, p. 161.

| | |
|---|---|
| Cu, | 0.58 |
| $Fe_2O_3 + Al_2O_3$, | 2.13 |
| ZnO, | 0.06 |
| MnO, | 0.12 |
| Co + Ni, | 0.02 |
| CaO, | 0.07 |
| MgO, | 0.04 |
| Alkalies, | 0.62 |
| Cl, | 0.13 |
| $SO_3$, | 2.39 |
| | 6.16 |

No inconvenience results from this addition, as the residue is not sold, but is used as a flux about the works.

After each operation an assay of the ore is made to ascertain how far the copper is leached out of it, and when this has been done, the vats are discharged to be refilled. The time taken to leach at Duisbourg is about forty-eight hours for each vat, and four to five of them are leached in a day. At Hemixem this second washing takes from seven to eight hours. At Oker the coke-tower liquors are allowed to remain twenty-four hours on the ore.

At Hemixem the whole operation takes from thirty-three to thirty-nine hours, generally about thirty-six. About 300 tons can be leached in twenty-four hours. The leached ore still contains from 0.25 to 0.30 per cent. of copper, and from 0.80 to 0.90 per cent. of sulphur, but it would not pay to carry the extraction any further. At Oker the time required is about fifty-three hours.

At Hemixem in the bottom of the vats and between the slats which form the false bottom, a compound is found containing 18 per cent. of copper, and so hard that it has to be removed with a pick. It is sold to the copper-works.

c. *Treatment of the Residues.*—The residue contains but little copper, but as it is to be sold, it must be leached to separate any chlorides of copper or other metals that may have been formed during the operation, as well as to wash out any sulphate of soda that may be present in the residue. It is, therefore, at Duisbourg and Hemixem, leached with hot water, which takes from two to three hours, and leaves the "purple ore," as it is called, in a condition to be sold. The exhausted material consists of an iron residue containing from 60 to 65 per cent. of iron. Its average composition from Rio Tinto and Hartz ores is:

| | Rio Tinto. |
|---|---|
| Sesquioxide of iron, | 96.00 |
| Lead as sulphate, | 0.75 |
| Copper, | 0.20 |
| Sulphur, | 0.36 |
| Lime, | 0.40 |
| Alkalies, | 0.10 |
| Residues, | 2.11 |
| | 99.92 |

| | Hartz. |
|---|---|
| Sesquioxide of iron, | 79 |
| Copper, | 0.3 to 0.8 |
| Alumina, | 3 |
| Manganese, | 1 |
| Lime, | 2.5 |
| Sulphuric acid, | 5.5 |
| Residues, | 6 |
| | 97.3 |

As it is practically free from phosphorus, and contains but little sulphur, it is much sought for as an ore of iron. It is used in the Siemens furnace in the pig-and-ore process. Much of the residue at Hemixem, where the daily production reaches 90 to 100 tons, is sent to Ougree to be smelted there in the blast-furnace. It is used as fettling in the puddling-furnace, where iron-works are in the vicinity. It is also used for making malleable iron castings and for the purification of illuminating-gas.

At Hemixem the exhausted ore is charged into cars and stored on the outside of the works, on a drained area, until sold. All the waters which drain through it are conducted with the spent liquors from the precipitation-tanks into a series of twelve vats in the open air, in which iron is placed to precipitate any copper which was not soluble in the vats, but which has become soluble by the reactions going on in the ore in the heap. The water running from the last of these vats is quite clear, and is allowed to flow off with the excess of acid waters. It does not contain more than 40 to 60 grammes of copper to the cubic meter of liquid.

4. *Precipitation of the Gold and Silver by the Claudet Process.*

The liquors resulting from the first leaching contain the gold and the silver which has been dissolved in the first washing, the silver being kept in solution by the excess of salt. These are collected in a special vat lined like the others with lead and painted on the out-

side with tar. This vat, according to the ground on which the works are built, is either in series with the others on an incline, or as at Duisbourg above the others, and so arranged that it can be made to communicate with any of the series of precipitation vats. Directly below it there is a vat into which all the precipitates are washed and collected until there is enough to make it worth while to treat them. The silver liquors are first settled, and are then raised into this tank; their silver and gold contents being known, the proper quantity of zinc iodide, dissolved in water with some plumbic acetate, is introduced at the same time as the other liquors. Its object is to precipitate all the silver and gold. During the whole time that the tank is being filled, it is kept constantly stirred to be certain of the intimate mixture of the iodide, and is then left to settle. This takes a very long time, at least forty-eight hours, as the precipitate is light. In order to collect it quickly at Oker, a mixture of glue and tannin, made by dissolving 600 grammes of glue in 10 liters of water, and adding to this 30 to 40 liters of tannin, made by boiling white-oak bark in water, is added to the vat. In twenty-four hours the precipitate is settled and the supernatant liquor is quite clear, and is ready to be drawn off. At Oker this is done through a lead pipe fastened to an upright board. The pipe is bent at right-angles at the bottom, the end being conical, and made of very hard lead. This fits into another hard lead cone attached to a pipe which passes through the side of the tank. The two are screwed together by a nut, which has a number of threads, and is provided with a slot at the back to be certain of its pressing tight against the pipe. The upright board to which the pipe is fastened is attached to a lever filled with holes at short distances so that it can be attached to a pin in the side of the tank. The top of the pipe can in this way be secured at any level below the surface of the clear liquid, which is thus allowed to run off into the copper precipitating-vats. No attention need be paid to it until the top of the pipe gets near the precipitate in the bottom, when it must be carefully moved. When the tank is to be recharged the pipe is made vertical when its top reaches above the top of the liquid. Generally the liquor is drawn off with a siphon, or through a hole in the side. In some works this precipitation is done only a few times, and the precipitate is then removed, but in the Hartz, and generally, it is done as often as from twenty-five to thirty times. It is then removed from the tank. At Duisbourg, where the precipitation-tank is above the others, this is done through a discharge-

hole in the bottom at the side of the tank which, during the operation, is closed by wooden stoppers 2 meters long, which reach above the top of the tank. Through the stopper near the top, a hole is bored for a round piece of wood, which serves as a handle. The stoppers are removed, and the precipitate in the bottom washed into the tank below. When this device is not adopted, the precipitate has to be first washed in the large tank and then scooped out, which takes a much longer time, makes the large precipitation-tank do the duty which could as well be done by a smaller one, and diminishes the output of the works by just so much. The sides of this tank are covered with gypsum, which is very rich in silver. When this crust is thick enough it falls of itself; the silver is then separated from it.

The precipitate must be washed seven or eight times with water to remove any trace of soluble material. It contains a considerable quantity of lead sulphate and chloride, a small quantity of the subsalts of copper, and the silver as iodide. The mass is kept stirred and pumped through a filter-press. The precipitate is reduced with zinc, to which some hydrochloric acid is added. The iodine goes to the zinc, which is used over again, and the other metals are reduced, but a considerable quantity of the iodine is not recovered. The waste is made good by the addition of iodide of potassium.

The result of the process is a precipitate containing much lead and very rich in silver, containing almost all of the gold. The amount of lead may be as high as from 50 to 60 per cent. The silver will vary according to the richness of the ore, but it will be between 3 and 5 per cent. The gold will not generally be much above 0.05 to 0.06 per cent. This material goes to the silver works to be treated. The cost of this process is exceedingly small, and when the plant is large enough the profit from the extraction of silver and gold is very large in per cent. The actual profit depends on a great many other things. In the Hartz this precipitate was formerly treated with sodium sulphide. The silver, with about 6 per cent. of copper, is transformed into sulphide. The whole is pumped through a filter-press.

### 5. *Precipitation of the Copper.*

The clear liquid containing the copper in solution is collected in lead-lined vats, thoroughly painted with tar on the outside. The vats are arranged so that the liquids flow easily from one to the other, and also, so that each one is independent of the other, and

may at any time be detached from the series, either to take out the cement copper or for repairs. Conduits are arranged everywhere, so that by means of siphons or of plugs the liquid from any tank may be emptied and carried to the place where it is to be stored. All of the liquors are heated by steam to the boiling-point. As they get cool it is necessary to heat them up two or three times. They should be kept carefully covered, both to prevent loss of heat and also the formation of insoluble oxychlorides. They are kept constantly supplied with iron, which is removed as it dissolves. The iron for the precipitation is whatever is available. From 1½ to 2 tons of it is piled into the vats roughly. Occasionally pieces as large as an ordinary car-wheel are put in. I saw at one of these works such a wheel, out of which all the iron had been dissolved, leaving only the carbon, which had exactly the same shape, and was so light as to be easily lifted with one hand.

At Duisbourg there are thirty-two of these vats, arranged in four rows of eight, each one being independent of the others. The vats are 2.50$^m$ long, 2$^m$ wide, and 1$^m$ deep.

At Hemixem the vats are arranged in three series, so that the liquors for each precipitation pass through one of those series, or can be run from one to the other, or any one or more may be detached when there is any occasion for it. The vats are 3.50$^m$ square and 0.80$^m$ deep. The liquor enters the vat on the top on one side, and passes out through a pipe on the other which goes to within 0.30$^m$ of the bottom, and so on through all the vats of each series. A partition in each vat forces the liquid to traverse the iron so that it is brought into most intimate contact with it. When sufficient copper has accumulated, the iron is lifted out and washed off in the liquid of the bath. The first vats are cleaned once a week, the last about once a month. From the last vat the liquid flows through to the outside of the works. Experience has shown that the amount of iron required, when the work of roasting has transformed the whole of the copper into $CuCl_2$, is one part of iron to one of copper precipitated, and this is the amount used at Hemixem and Oker, when the operation has been so conducted as to prevent the formation of ferric salts, which dissolve the iron to no advantage, and cause a loss of copper as oxychlorides. When the ores contain arsenic and antimony these will be dissolved with the copper and will be precipitated with the iron. In some of these works these impure liquors are exposed to the air, so that insoluble compounds of arsenic and iron are formed, and if there is much

antimony it is precipitated with lime. There is, however, danger that insoluble oxychlorides of copper will be formed at the same time, and unless the amount of impurities is considerable, it is best not to run the risk of a loss in copper, as in any case the whole of the arsenic will not be separated. If there is only a small quantity it can be separated in refining.*

With so large a number of small launders and vats it is impossible to prevent leakage. As the waters are valuable, the flooring is made of asphalt, and is water-tight. It inclines to a sump in which all the leakages are collected. From here they are raised by an injector to a tank, from which they flow through launders 180 m. long, containing some iron. They usually contain about 1 kilogram to the cubic meter when they enter the launder; when they leave it they do not contain more than 75 grams. From the launder they run to the outside vats. The liquors are heated by steam to 45° to 55° C. There is a very great advantage in working with a partitioned vat. By making the solution pass up through the iron and from one vat to the other, the number of vats as well as the quantity of iron used is reduced, and the output is greatly increased.

The precipitated liquors which contain the iron, and but little copper, are run off by a siphon from the side into a lateral trough, or are drawn through the bottom of the tub. When they are drawn by a siphon they must be left a certain time to settle, and all the liquid drawn below a certain level must be carried to tanks to settle. When they are drawn from the bottom as at Oker, it is usual to place a filter, generally made of hair, at that point.

When the tank is empty the copper is shoveled out. At Duisbourg two of these tanks are emptied each day, and produce from 2000 to 2500 kilos. of cement-copper.

The copper-vats on the level, after the copper has been precipitated by iron, are emptied by siphons into a trough in the aisle between the tanks.

### 6. *Treatment of the Cement-Copper.*

When the precipitation with iron has been carried so far that all the small pieces have been dissolved, the large ones are lifted out and the cement-copper is removed. At Duisbourg this is done every two weeks; at Hemixem every week or ten days; at Oker every four weeks. The time is not a matter of much consequence so long

* *School of Mines Quarterly*, vol. iv., p. 9.

as the liquors are not exposed to the air, and depends mainly on the use to which the cement-copper is to be put, whether it is to be sold or used in the works. It is usually all of one quality. When, however, the ores contain much arsenic and antimony, the liquors from the last two washings contain so much of it that they are kept separate, so that the cement-copper from the treatment must be looked on as very impure, and must be treated with ores containing an excess of sulphur in order to remove the arsenic and antimony. If there is not much of it, it is refined, but kept separate, and sold as an impure product.

At Duisbourg and Hemixem it is washed with a stream of water, on a grating made of copper bars, to remove any traces of acid, and also of undissolved pieces of iron, which are carefully picked out and used in the launders. As the copper crystals are small, they, with the small pieces of iron, pass through the grating, and are collected in a vat below, which is constructed with a series of steps. The best copper is collected on the first steps, the two steps below do not give as good copper, and, finally, the fines are carried upon a series of planes where a screen with meshes 8 or $9^{mm}$ fine collects the copper. These products are not kept separate unless the ore contains a considerable percentage of arsenic, in which case the separation is made with the greatest care, as the fines contain the most of it. When the cement-copper cannot be washed at once it oxidizes, and to remove the oxide it is washed with acid water. This is all collected and added to the other liquors containing copper. At Oker the washing is done on an inclined plane and is only approximately done. The cement-copper contains from 75 to 80 per cent. of copper.

The analysis of this cement-copper according to Bräuning is as follows:*

| | |
|---|---|
| Cu, | 77.45 |
| Pb, | 0.63 |
| Ag, | 0.10 |
| Bi, | 0.006 |
| As, | 0.04 |
| Sb, | 0.15 |
| $Fe_2O_3$, | 6.72 |
| $Cl_2O_2$, | 0.99 |
| Zn, | 1.02 |
| Mn. | 0.02 |
| Co + Ni, | 0.03 |

* *Zeit. für Berg-, Hütten-, u. Salinenwesen*, vol. xxv., p. 162.

| | |
|---|---|
| CaO, | 0.10 |
| MgO + alkalies, | 2.71 |
| $SO_3$, | 4.58 |
| Cl, | 1.19 |
| Insoluble in acids, | 0.61 |
| Acid and moisture, | 3.654 |
| | 100.000 |

The mean of a number of analyses at Hemixem was:

| | |
|---|---|
| Copper, | 75.07 |
| Lime, | 1.28 |
| Alumina, | 2.36 |
| Manganese, | 0.99 |
| Protoxide of iron, | 5.80 |
| Sulphate of soda, | 2.04 |
| Chloride of sodium, | 0.55 |
| Water, | 8.00 |
| Insoluble, | 4.10 |
| | 100.19 |

When from 8 to 10 tons have collected it is taken out on to a draining-floor and left until no water flows from it. It is then dried on a floor heated for the purpose, five or six tons being treated at a time, which is spread out to a thickness of 15$^m$. It is turned over every two or three hours, and at the end of twenty-four hours it will contain not more than 8 to 10 per cent. of water. In some of the works it is barrelled and sold in this condition. Here it is made into bricks in an ordinary brick machine, or in a hydraulic press. There is a great advantage in using the press, both for uniformity and celerity of action. It gives the copper in a compact form, and prevents the oxidation, which takes place very rapidly when cement copper is exposed to the air—the more completely as the pressure has been greater. The hydraulic machine can also be worked with cheap labor, but no advantage over the ordinary brick-machine is gained unless the quantity to be treated is sufficiently large to have the machine so constantly in operation that it must be kept in good working order.

The cakes of compressed copper are 0.2$^m$ by 0.12$^m$ by 0.23$^m$. They are dried on a rack in the air, packed in barrels, and shipped still moist. They contain about 85 per cent. of copper. When they are not completely dried the copper oxidizes. At Hemixem the transmission of the power from the engine was by means of ropes. It has been found more expensive to turn the *v* grooves in

the pulleys, and the cords are also more expensive to fix, but they can be run very loose. The expense of repair is very slight.

### 7. *Fining and Refining the Copper.*

The copper is refined at Hemixem in a blown furnace, which is blown up to the poling. The air is cold, at a pressure such that the leather boot can be pressed with the fingers without effort. Soda is used just after the slag is taken off, in order to eliminate some of the arsenic. The slag is treated in a shaft-furnace with four tuyeres supported on columns. The top is built on an iron ring; the bottom is free to be torn down. The slag runs into two iron basins, and contains 1½ per cent. of copper. At Oker there are two fining and two refining furnaces of the English type. In these the copper matte of the works is fined and granulated for making the sulphuric acid; the other furnaces are used for making plates for the separation of the precious metals by the electrolytic process. For granulating, two charges of 60 centners each are made, and 65 centners of granulated copper are obtained. For the other furnaces a little better result is got, but the cement-copper oxidizes very rapidly, so that it will not be much over 80. It is kept in powder.

It is not profitable to use the process described in this paper when the ores contain more than 8 per cent. of copper, on account of the formation of subsulphides of copper which are not acted on, but whose formation cannot be prevented in roasting rich ores. It is necessary that the ores be as free as possible from any gangue which will remain attached to them. It is necessary that both salt and iron should be very cheap, but this process might be advantageously employed in cases where fuel is dear. It can only be used where labor is cheap or where the lay of the ground is such that the enormous amount of moving which must be done can be carried on automatically as far as possible; for which reason it is better to select a location where the ground is not level. If there is no market for the residue, some way of reducing the iron residue should be devised in order to use it as sponge in precipitating the copper, as the heaviest single item of expense will be the iron. The amount of it consumed will be small if no ferric salts are allowed to be formed. The extraction of all the metals is very complete, that of the copper being about 98.5 per cent. when the work is carefully done. In ore varying from 0.005 to 0.015 per cent. of silver, nearly 80 per cent. can be depended on. The plant is not very expensive,

and the process is cheap if the residues are treated. If an acid-works has to be constructed expressly, the amount of return for the capital involved will depend for the most part on the acid-works.

The process requires great skill and careful watching in all its parts, which is its greatest disadvantage; and when the ores contain much arsenic and antimony, it loses most of its advantages, as these are precipitated with the copper with as much exactness as the other metals. By separating the liquors and putting up with a small loss of copper, this may be reduced at times to a minimum, but the extra cost of refining will generally compensate for any advantage gained. When, however, they are pure, the process can be made exceedingly profitable on very poor ores, as has been done in England.

---

## *THE MANUFACTURE OF STEEL CASTINGS.*

BY P. G. SALOM, PHILADELPHIA, PA.

THE manufacture of steel castings has become one of the important industries of the times. The late Mr. Alexander L. Holley published in 1878, in the *Metallurgical Review*, an able paper, entitled "Solid Steel Castings," showing how all manner of castings could be made advantageously of steel. Mr. Holley had then but lately returned from the great iron and steel works of Terrenoire, France, which were engaged, I believe, almost exclusively on large castings, of a simple type, for the government, and were repeating the same operation from day to day. These conditions are, as experience has shown, very different from those of ordinary practice in miscellaneous castings; and Mr. Holley might have been less confident if he had actually gone into the business. More than seven years have passed; and as yet the magnificent possibilities held forth in his paper have not been realized. There are only six steel-casting establishments in the United States, and their total output of castings is certainly not as much as 20,000 tons per annum, and probably not more than 10,000 tons; whereas it should be over 200,000 tons to supply the needs of the country.

A large number of so-called steel castings are made, however, which are nothing more than malleable iron. The best of these castings are made from a superior *white pig, as low in silicon and*

*phosphorus as possible.* They are made in the same manner as ordinary iron castings, except that the metal having so little silicon chills much quicker than ordinary No. 1 foundry iron, and the liability to shrinkage-cracks renders it necessary to put large "rising-heads" on the castings. The castings, after cooling, are very hard and almost as brittle as glass, and are, or should be preferably, perfectly *white* throughout. They are then annealed in ore or scale, to which a little sal-ammoniac has been added. This latter operation, which requires about two weeks, produces on the entire surface of the casting a coating of malleable iron, about $\frac{1}{16}$ of an inch thick, and renders the inside sufficiently soft to be tooled without any difficulty. For small castings such a metal is admirably adapted; but castings several inches thick made in this way are only slightly superior to good pig-iron in having, perhaps, a little greater tensile strength.

What then are the reasons, in view of what has been said above, for such a small production of genuine steel castings?

This question is best answered by a short description of the three general methods employed in the manufacture of steel castings, viz.: the crucible, the Bessemer and the open-hearth processes.

## Crucible-Steel Castings.

I have no hesitation in saying, and say it without fear of contradiction, that crucible-steel castings are a failure and always will be. I do not mean by this statement to say that it is impossible to make crucible-steel castings satisfactory. But with the single exception of a particular class of work where hardness and ultimate strength are alone desired (for which requirements they are well adapted), there are always a number of disturbing elements that will eventually result in the total disuse of crucible-castings. The value of small steel castings depends on the possession of qualities that render them equal or superior to forgings. When it is attempted to make a steel with the requisite qualities the troubles begin. First, in order to get such a steel, muck-bar must be used almost exclusively. This, as every one knows, is very difficult to melt in a crucible-furnace; and after melting it is almost impossible to pour it, as the metal chills before the pots can be emptied. If, however, after unusual exertions, a successful cast be made, the castings are found to be full of blow-holes. There are two means employed to remedy the latter defect: first, by the use of ferro-silicon, and second, by making a

steel higher in carbon and therefore more fusible. When sufficient ferro-silicon is added to give from 0.5 to 1.0 of silicon in the steel, the metal is not difficult to melt; but the resulting castings, while soft and solid, have lost all their ductility, and are simply a superior form of pig-iron, with a tensile strength of about 50,000 lbs. If, on the other hand, the pots are charged with stock higher in carbon and only a small percentage of ferro-silicon is added, the castings are solid, but are brittle, and so hard as to be difficult to tool. Their hardness is extremely objectionable to machinists, but their brittleness is a still greater evil, and precludes the possibility of their replacing forgings. In has been attempted to overcome the latter difficulty by annealing; and by this means a really superior crucible-casting can be made. But the additional cost of production is greater than consumers are willing to pay for the castings.

### Bessemer Steel Castings.

The application of the Bessemer process to the manufacture of steel castings in this country was first made by Mr. Hainsworth, of the Pittsburgh Steel Casting Co., who has achieved a more notable success in steel castings than perhaps any other man in the United States. The Bessemer process, however, in the manufacture of steel castings, is as yet open to the objection of making a less homogeneous and a harder metal than the open hearth. Some months ago, I saw a number of large Bessemer steel cranks, weighing from 7000 to 8000 lbs. each, that had broken in half when it was attempted to shrink them on the shafts for which they were intended. A number of open-hearth cast-steel cranks of the same size, made at the Chester Rolling Mills in 1882, easily withstood the shrinkage-test and are still in service. Notwithstanding the failures in this respect, which have greatly prejudiced consumers and prevented thus far a more general adoption of steel castings, I believe that in a few more years all steel castings will be made by the Bessemer or an equivalent pneumatic process.

### Open-Hearth Steel Castings.

I am glad to be able to say positively that this method can now be relied upon to make a very large class of important castings with entire success. Mr. Holley has given such a thorough and admirable description of this process that I cannot refrain from quoting it in part, omitting details, after which I will confine my remarks to

some of the difficulties that a practical study of the subject has developed, and to the chemical and physical qualities of the castings. Mr. Holley says:*

"The operation consists:

"1. In the formation of an initial bath of manganiferous pig to prevent oxidation during the process.

"2. In dissolving such softening or decarbonizing materials as wrought-iron in this bath.

"3. In the addition, at the end of the operation, of silicon and manganese in such order and proportion as to prevent the formation of blow-holes while casting, and at the same time give to the steel certain special physical qualities.

"Another very important feature of the process is the method of taking tests. We will now describe in detail the different stages of the operation, and we will suppose at first, so as to avoid confusion, that the metal to be produced is of the harder kind.

"*The Furnace.*—The object of greatest importance during the whole of the operation is *to keep oxidation as low as possible in the bath.* For this reason the furnace must, indeed, be kept as hot as possible, with a good solid body of flame; but there should be only just enough air admitted to promote thorough combustion.

"*The Initial Bath.*—This must be made of pig-iron containing from 6 to 9 per cent. of manganese. Spiegeleisen is probably the most convenient form of pig; but as spiegel with this percentage may not be at hand at all times, the bath may be formed by taking a richer spiegel, say 12 or 14 per cent. manganese, and diluting it with one-half ordinary pig containing no manganese. . . . .

"The weight of the initial bath, in proportion to that of the whole charge, varies according to the conditions under which the heat is made. We may say, generally, that 11 per cent. of the whole is an average quantity. Every open-hearth melter knows that it is impossible to determine in advance the exact quantity of pig wanted for the operation. The temperature of the furnace has much to do with it. The nature of the refining material has also a great influence. If a specially pure product is required and the softening materials used are very fine puddled blooms, nearly free from carbon and manganese, the initial bath must necessarily be larger, as well as richer in manganese, it may in this case reach 14 per cent. of the whole charge. The materials for the initial bath are always charged cold. . . . .

"*The Softening or Refining Materials.*—Soon after the bath is completely melted, the refining materials are successively added in small lots of about 450 lbs. each. These are invariably preheated, as charging them cold and frequently would tend to keep down the temperature of the bath. . . . .

"The materials used in this second period of the operation are chosen with reference to the quality required in the finished product. They may be good Bessemer or open-hearth scrap, fountains from previous castings, puddled bars or direct blooms. Materials inferior to these would correspondingly lower the quality of the product. . . . . The proportion of refining materials to the whole charge averages 78 per cent. . . . .

"*Slag-tests.*—Spiegeleisen is used for the initial bath, because the manganese it contains, being the most oxidizable of all the materials present, will remove oxygen

* *Solid Steel Castings for Ordnance, Structures and General Machinery by the Terre-noire Process.* By A. L. Holley, C.E. (Reprint from the *Metallurgical Review*, New York, 1878, vol. ii., p. 205.)

that may be present in the bath, and will intercept oxygen that tends to enter it. So that the more manganese there is in the slag the less oxygen there will be in the metal below. Oxide of iron tends to make the slag black; manganese turns it light olive or ash-green, and the different tints between these two extremes give to the practiced eye an exact idea of the state of the oxidation of the bath. . . . .

"*Metal-Tests before the Final Additions.*—The slag-test gives no indication of the physical state of the metal, which is an equally important guide in the operation. When, therefore, the operator has reason to believe that the metal is approaching the point of sufficient softening or purification, he makes the following tests: A ladleful of metal is taken from the furnace and cast into a round ingot about 3 inches in diameter and 1¼ inches thick. The ingot is knocked out of the mould as soon as set, and flattened under a special steam hammer, at its original heat, into a disk about 7 inches in diameter and ⅛ of an inch thick. . . . . From bending and fracturing these disks the operator can judge of the state of his metal with great nicety, and has at hand all the necessary elements to remedy any unfavorable tendency likely to develop during the operation. . . . .

"*The Final Additions.*—These consist of a special pig, containing both silicon and manganese and also an additional quantity of manganese introduced in the shape of a 50 or 60 per cent. Mn ferromanganese. A part of these ingredients is taken up by reactions which prevent the formation of blow-holes; the remainder is left in the metal to impart to it certain physical qualities. The usual charge consists of 11 per cent. of special pig, having the following composition:

| | |
|---|---|
| Mn, . . . . . | 3.50 |
| C, . . . . . | 3.00 |
| Si, . . . . . | 4.20 to 4.60 |
| P, . . . . . | 0.10 |

". . . . The proportion of ferromanganese used varies from 1 to 1.8 per cent. of the total charge. . . . .

"The special pig is charged hot. While it is melting a marked change takes place; the bath, which up to that time had bubbled about as much as in the ordinary pig and scrap operation, becomes gradually more and more quiet until its surface is smooth and scarcely broken by small and widely scattered bubbles. When the special pig is nearly all melted, the ferromanganese is thrown in hot. The bath is then rabbled vigorously for about a minute, and casting takes place immediately."

The Standard Steel Casting Co., Thurlow, Pa., of which the writer was lately president, found it possible in practice to simplify many points in the above method, securing equally good results. None of the stock is preheated except the final additions, and the refining materials are charged at once.

The two principal difficulties that the steel-foundryman has to contend with are blow-holes and shrinkage.

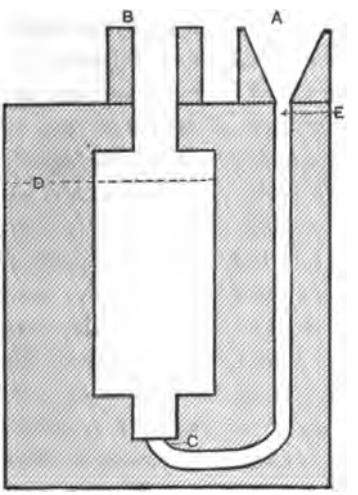
### *Blow-Holes.*

It is commonly supposed that blow-holes in castings are due to carbonic acid gas, disengaged during the operation of casting. This

is only true to a very limited extent, especially where the steel contains 0.1 per cent. or more of silicon. Herein lies the cause of the many failures connected with the manufacture of steel castings. The manufacturers had been led to believe that it was only necessary to add a few pounds of ferro-silicon to their steel, and presto! all the castings would be solid. Practical experience has proved the fallacy of this idea.

Blow-holes in steel which has been properly melted, and to which has been added sufficient ferro-silicon, are almost entirely due to the high melting-point of low-carbon steel, or rather to the rapidity with which the metal chills. This is proved by the fact that the lower ends of castings which have been fed from the bottom by means of a runner are always solid, while the blow-holes, when such exist, are always on top. Out of the thousands of castings we have made, I have never yet seen a single one with blow-holes where the gate

FIG. 1.




Mould for Casting a Plain Roll.

joined the casting. The metal does not remain fluid long enough to allow the air and other gases, that are mechanically carried into the mould, to escape.

This is best illustrated by reference to the accompanying sketch, Fig. 1, which represents the manner of casting a plain roll. *A* is the fountain-head or basin where the metal passes from the ladle into the mould; *B*, the rising-head; *C*, the point where the runner joins

the roll; *D*, the point where the casting is liable to defects from blow-holes. The reason for this is obvious. If water from a faucet passes through a tube it carries the air along with it. If we could instantly congeal the water, the resulting ice would be full of holes. So it is with steel, only more so, since the molten metal is not nearly as fluid as water. As a consequence of the metal meeting the relatively cold mould, by the time the metal reaches the top of the mould it is very much less fluid, in fact, almost pasty, against the sides, and solidifies instantly without further provocation. If there are any corners, the air is confined in them, and in its efforts to escape through the pasty mass, furnishes (as a cooling agent) the last requisite necessary to solidify the metal. The air is thus imprisoned, and the casting defective. What is necessary, therefore, for a perfect casting in the above case, or, indeed, in any case, is a free circulation of the metal. If the mould can be obtained full of fluid metal, the resulting casting will be solid, that is, free from blow-holes. It may have a hole in the centre due to shrinkage, but such holes are entirely distinct from blow-holes, as will be explained below, when I come to speak of shrinkage.

The difficulty connected with blow-holes, as will be seen by an inspection of the 2000-pound cast-steel roll before you, we have almost entirely overcome by putting on top of the casting a rising head from 2 to 3 feet high. By this means we have been able to make 6000-pound steel rolls *without a single blow-hole or flaw of any kind*, and now we rarely lose a casting of this simple type.

The long riser is effective in two ways: first, it carries from the casting proper the sluggish metal, which has been cooled in its passage through the mould, and allows the mould to be filled with hot fluid metal; and second, the ferrostatic pressure of a column of iron 3 feet high is equal to about 10 pounds to the square inch. This pressure has a tendency of course to force the metal into all the corners and make it solid. It also prevents, in a measure, shrinkage-troubles, and appears to give to steel castings that solidity for which they are noted, giving them a density of 7.8, almost equal to that of a forging.

### *Shrinkage.*

The second serious trouble encountered by the steel-foundryman is shrinkage. This presents a difficult and troublesome problem, which has not as yet been fully solved. It is almost impossible to make certain large, thin, complicated castings of steel. Shrinkage-

troubles are caused by the immense contraction of cast steel, which frequently amounts to $\frac{5}{16}$ inch per foot; and to the hard dry sand moulds, which it is necessary to use, in order to prevent the white hot metal from destroying the mould.

There are five different ways of attempting to remedy this evil:

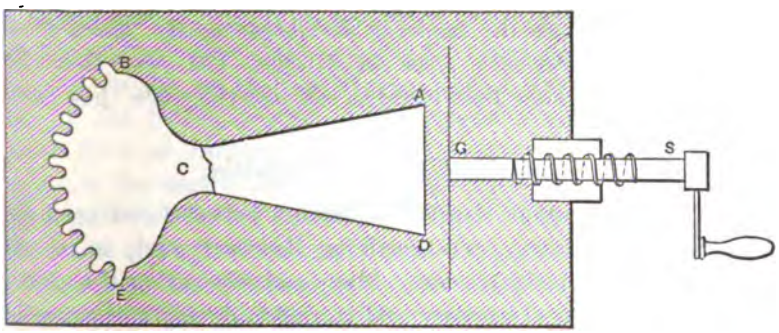
1. By changing the chemical constitution of the steel.
2. By stripping the castings as soon as poured.
3. By mechanical pressure.
4. By large rising-heads.
5. By care in moulding.

*Chemical Constitution.*—A change in the chemical constitution by increasing the manganese and diminishing the silicon, will nearly always have the desired effect. This renders the metal more fluid, and lowers its melting-point.

*Stripping.*—A large number of castings can be saved from tearing apart or cracking when cooling, by simply opening the flasks immediately after pouring and covering the casting with sand.

*Mechanical Pressure.*—We have been able to save quite a number of difficult castings by means of mechanical pressure. For example,

FIG. 2.




Sectional Plan, showing Screw-Arrangement to Prevent Shrinkage-Cracks.

at one end of a flask, and immediately at the end of the moulding, a small iron plate is placed. This plate is attached to a screw which can be turned from the outside of the flask. The arrangement is admirably adapted for castings large at both ends and small in the middle. Suppose, for example, we have a long lever-gear casting to make, such as is sometimes used for hay- or cotton-presses. In such a case the shrinkage is away from the centre in both directions, as will be seen by reference to Fig. 2. In this figure, which presents

a sectional plan of the mould containing such a casting poured "on the flat," *A D* is prevented from drawing towards *B E* by the hard sand between, and, as a consequence, the casting is apt to break in two at *C*. By forcing the iron plate *G* against *A D*, by means of the screw *S*, the sand is broken and allows the casting to contract without straining or cracking it.

*Rising-Head.*—A large rising-head prevents shrinkage-cracks by the pressure it exerts, and by feeding the metal to points where shrinkage is taking place.

*Moulding.*—Many castings can be saved from shrinkage-cracks by an intelligent moulder. It would be useless for me to enter into details on this subject. Suffice it to say that every pattern is a study; and it is only by an intelligent application of the knowledge already gained, that it is possible now to make castings that a few months ago it would have seemed ridiculous to attempt.

### *Shrinkage-Holes.*

Shrinkage-holes in castings are exactly similar to the phenomenon called "piping" in crucible steel. They are very troublesome and difficult to prevent, although they rarely affect the value of a casting, coming as they do in the center. They are caused, of course, by the metal chilling before the immense shrinkage occurs. Then when this contraction does take place on all sides, but away from the center, there is no more fluid metal to run into the space thus made vacant.

### *Physical and Chemical Properties.*

The most important chemical difference between cast steel for castings, and ordinary open-hearth or Bessemer steel, is in the amounts of silicon they contain. Many eminent authorities maintain that silicon is a hardener and increases, therefore, the tensile strength, like carbon (although in a lesser degree); but I have not found this to be the case in my experiments. On the contrary, I have always found it to diminish the tensile strength, and when above 0.5 per cent., to destroy almost entirely the elongation or ductility, making the metal very red-short, and brittle when cold. It may have been that the silicon in the steel that we tested was present as silicic acid, but this could hardly be the case in samples made by the crucible-process in black-lead pots. Such steel made from the best Bessemer muck-bar, to which had been added sufficient ferro-silicon to make over 0.5 per cent. of silicon in the steel, only

showed a tensile strength of from 40,000 to 50,000 pounds per square inch in perfectly solid test-bars, whereas the same mixture with less silicon (but higher manganese, however) invariably gave higher tensile strength. The only explanation that I can suggest which will at all account for the exactly opposite conclusions of the above-mentioned eminent authorities, is, that it is probable that silicon exists in steel both as combined and as graphitoid silicon. In the former case, it might act like combined carbon and be a hardener; in the latter it would act like graphite, and undoubtedly would be at least indirectly, or, so to speak, negatively, a softener.

Another important difference is the comparative wide limits between which the carbon, silicon, and manganese may vary in castings, without affecting to an important degree the physical results. Such wide variations in steel rails or plates are now quite unknown.

The influence of carbon on steel is better known than that of any other substance which enters into its composition. No one, however, so far as I am aware, has done anything more than formulate the general law that tensile strength increases with the carbon, other things being equal. I have made the interesting observation, that this increase is almost exactly 1000 pounds for every 0.01 per cent. of carbon. That is to say, assuming 0.01 per cent. of carbon to be a unit of carbon, then if to 45,000 pounds (the tensile strength of pure wrought-iron) we add as many thousand pounds as there are units of carbon, we shall be able to make a very close approximation to the tensile strength. Boiler-plate steel, for example, has about 0.15 of carbon, and $15{,}000 + 45{,}000 = 60{,}000$ pounds, or about the tensile strength of boiler-plate steel. Rail-steel has about 0.30 carbon, and $30{,}000 + 45{,}000 = 75{,}000$ pounds, or about the tensile strength of rail-steel. Again, crucible-steel contains from 0.50 to 0.85 carbon, from which numbers we get in the same way, 95,000 and 130,000 pounds respectively, which include the range of tensile strength of various kinds of tool-steel. Still again, a sample of spring-steel showed 1.0 carbon; its tensile strength should, therefore, be 145,000 pounds. Its actual tensile strength, as tested at Altoona, was 143,000 pounds.

Of course this law only holds good where other things are equal. An undue amount of one or all of the other foreign substances that enter into the composition of steel, or unusual physical conditions, would change the results entirely. It may be of value, however, as an indication that, when steel with a known amount of carbon does not possess a certain tensile strength, then the other substances

entering into its composition are present in undue proportion, or it must have been made under unusual physical conditions.

The above law is not applicable to castings, where the presence of so much silicon affects in a notable degree the tensile strength derived from a given amount of carbon, and the physical properties are also affected by the fact that the metal has not been worked.

Manganese plays an exceedingly important and valuable part in the manufacture of steel castings. Low-carbon steel, to which has been added about 0.3 per cent. of silicon, is very pasty, and can be poured, without chilling, into the largest castings only. Manganese will correct this trouble to a great extent, although somewhat at the expense of softness and ductility. The castings, however, as we have seen above, are more apt to be solid and less liable to crack in the moulds, the metal being much less red-short.

We must remember, in studying the physical characteristics of steel castings, that we are dealing with a material that has not been worked in any way, either by the hammer or rolls.

I give below the results of a few chemical and physical tests:

| Test No. | Carbon. | Silicon. | Manganese. | Tensile strength. | Elongation in 2 inches. |
|---|---|---|---|---|---|
| 3 | .11 | .49 | .61 | 63,000 | 12 per cent. |
| 4 | .23 | .19 | .43 | 68,000 | 12 " |
| 6 | .38 | .39 | .25 | 55,000 | 9 " |
| 29 | .27 | .38 | .39 | 70,000 | 8 " |
| 120 | .28 | .26 | .38 | 64,000 | 7.5 " |

I also give the analyses and tests of the Terrenoire metal:*

| Charge No. | Carbon. | Silicon. | Manganese. | Tensile strength. | Elongation. |
|---|---|---|---|---|---|
| 2078 } | .26 | .26 | .41 | 66,500 | 12.8 per cent. |
| 2262 } | | | | 68,000 | 13.8 " |
| 18 | .317 | .30 | .48 | 80,700 | 14.8 " |

The physical tests in both cases were made on the raw metal; annealing about doubles the elongation without greatly affecting the tensile strength.

It will be seen from the above tables that the steel made by the

* From Mr. Holley's paper, already cited.

Standard Steel Casting Company compares favorably with that of Terrenoire, which is the best cast steel of which we have any records.

The steel in the case of the last three tests in Table I., was not made for the purpose of developing the highest possible elongation.

Notwithstanding the excellent results that have been obtained at Terrenoire and other places on the continent, I am convinced, after a careful study of the subject, that the highest attainable physical qualities in a casting can only be secured by compression. That is to say, although we are now able to make perfectly solid, soft, strong steel castings, having a reasonable amount of ductility, the solidity is obtained at the expense of the ductility. Now if we were able to retain this ductility to its greatest possible extent, a casting would be of far greater value than a forging. This can be secured by compression, or by no-silicon steel, if consumers could be educated to use steel with blow-holes. A case in point is the forged steel shaft of the "Dolphin." A shaft cast to its shape under compression would never have broken under the same test. Even an ordinary steel casting would have been far superior to that shaft; for the metal would at least have been solid, and free from that spongy unworked condition due to heating up and cooling down, and to the insufficient power of the hammer to properly work the metal.

There is a popular fallacy in this country, that steel castings can be made in England and on the continent without any trouble from blow-holes. But the *Mechanical World*, of February 7th, 1884, speaking of Mr. Alfred Davy's process says: "If Mr. Davy opens up to iron founders, a means of making either steel or iron castings with little more than iron-foundry plant, he will confer a benefit on the engineering profession. Perhaps he can also show the users of his patents how to make sound steel castings. If so, much will have been done, for those much to be desired articles are yet a rarity even in the most advanced establishments."

The Standard Steel Casting Company has been unusually successful with large castings. Its works have made a greater technical success, in a shorter time (the open-hearth furnace having been in operation only nine months), perhaps, than any steel foundry that has ever been established. They have recently executed an order from the Edge Moor Iron Company of Wilmington, Delaware, for a cast-steel housing for a hydraulic upsetting-machine. The casting, when finished, weighed a little over 27,000 pounds, and is, un-

doubtedly, the largest steel casting that has ever been made in this country.

This proves that we are abundantly able to produce in the United States the heaviest castings for ordnance if the government would only pay reasonable prices and make reasonable specifications.

---

## *THE DURHAM BLAST-FURNACE.*

BY B. F. FACKENTHAL, JR., RIEGELSVILLE, PA.

THE Durham Iron Works of Messrs. Cooper & Hewitt, near Riegelsville, Pa., occupy a site which has been almost continuously the scene of iron-manufacturing industry since 1727. Doubtless if Anthony Morris and his thirteen associates, who in that year erected a blast-furnace on the Durham Creek, a short distance above where the Durham Iron Works now stands, could have had a vision of the improved and enlarged apparatus of their successors, they would have been not less astonished by the huge stack, the hot-blast ovens, and the blowing-engines of the modern blast-furnace, than by the railroad which now follows the bank of the river on which their clumsy "Durham boats" once floated pig-iron to Philadelphia. In one particular, posterity must confess their superiority. We are told that in November, 1728, they shipped three tons of Durham iron to England. The proprietors of the Durham Iron Works are not now shipping iron to England.

The present Durham furnace was built (in place of two smaller ones) in 1874 and 1875, and made its first blast in 1876. A description of it, with other works of the same proprietors, at Trenton, N. J., by A. L. Holley and Lenox Smith, was published in London *Engineering* for January 31st, and February 21st, 1879. Since that time, a number of improvements, dictated by experience, have been made in the details of the furnace and fittings; and the recent conclusion of a long and successful blast presents a convenient opportunity for a description of the works and a statement of the results of practice.

The accompanying drawings will show the general arrangement of the works. The furnace, Plate I., Figs. 1 and 2, is 75 feet high by 19 feet bosh. The hearth is 11 feet 4 inches in diameter, with seven tuyeres 5 feet 6 inches above hearth-line. The tuyeres project 9 inches into the furnace, making the interior tuyere-circle 9 feet 10 inches in diameter. The front is a modification of Luermann's

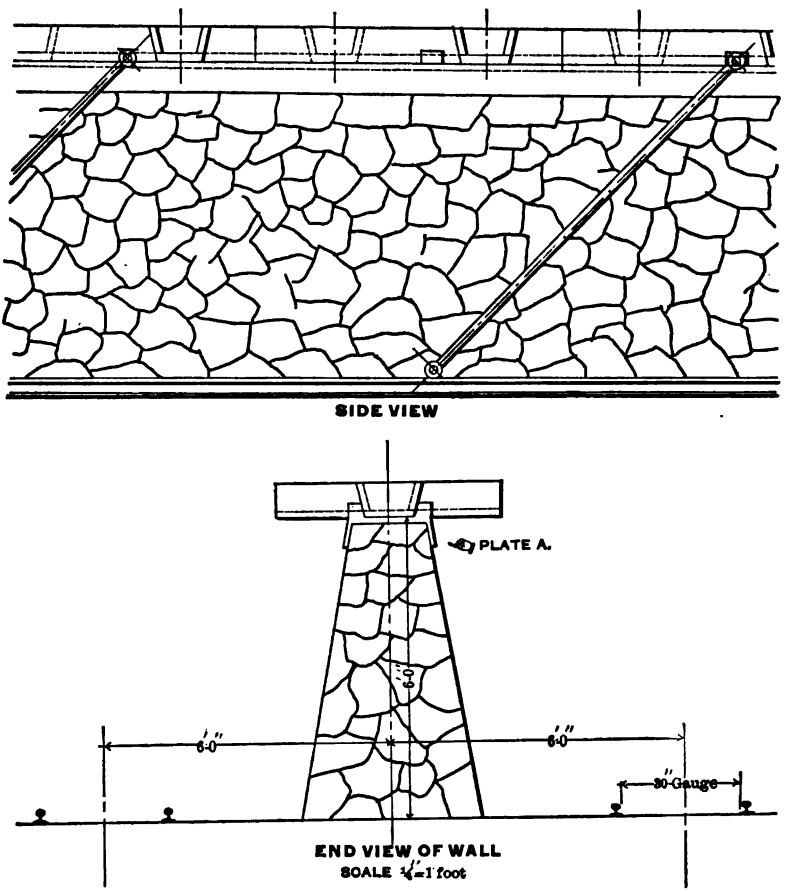
patent. The dam, Plate I., Fig. 3, is made in two sections. The outside plate is 4 feet 3 inches wide, with an inside dam 22 inches wide fitting into it. The opening in the small dam is 28 in. long. In case of any chilling in the hearth this inside dam can be removed, which would permit the opening of a tapping-hole 3 feet above hearth-line. The small dam can be replaced at any time without taking the blast off the furnace. By this arrangement, moreover, the large or outside dam is protected, and lasts indefinitely. One dam has served us for two blasts (five years) and is still in good condition. The small or inside dam taken out at the end of the last blast had been in use twenty months. Both dams are made flat and recessed into the brick-work, thus bringing them (at the tapping-hole) 10 inches nearer the inside of the hearth-walls. In this way, we think, the cooling is made more effectual, the tapping-hole better protected, and the breaking out of iron rendered less likely. During the blast just ended, of almost three years, we have not had a break-out around these dams.

The cinder-notch is placed 18 inches below the line of the tuyeres. It is made of bronze, has an opening of 1¼ inches, projects 3 inches inside of the hearth-walls, and is protected on the outside by two iron pipe-coils.

An arrangement for an extra or provisional cinder-notch is built into the furnace-wall opposite the regular cinder-notch. The cinder flows continuously, and is not flushed. It is taken off at the side of the furnace, and run into cars through a system of troughs, as shown in Plate I., Fig. 4, at T, U, and W, details in Figs. 7 and 8. By this arrangement we can place cars enough under the spouts at one time to hold the cinder made during from eighteen to twenty-four hours. The advantage of this is that the cinder is allowed to cool before the car is moved, which saves the leaks usually caused by pulling the cars out as they are filled, and bumping them together. Moreover, less clay or other packing is needed for the bottoms of the cars; and considerable labor is saved, as also the expense of horses to do the switching. When the cinder is sufficiently cooled, the cars are run into the yard by gravity, and are then taken to the dump by a locomotive. All dumping is done during the daytime. We use a circular cast-iron car, having found this shape of body less liable to break by expansion than a square or rectangular one; besides, the circular car is more convenient, and can be dumped at any angle. We have noticed that dumping cold cinder extends our dump faster, but as we have plenty of room we do not care for this.

The furnace is filled with a double bell-and-hopper, designed by Mr. Edward Cooper. This is shown in Plate I., Figs. 5 and 6. The small or inside bell is 3 feet 8 inches, and the outside bell 10 feet 6 inches in diameter. The furnace-top is 14 feet 2 inches in diameter at the stock-line, and the stock delivers within 22 inches of the walls.

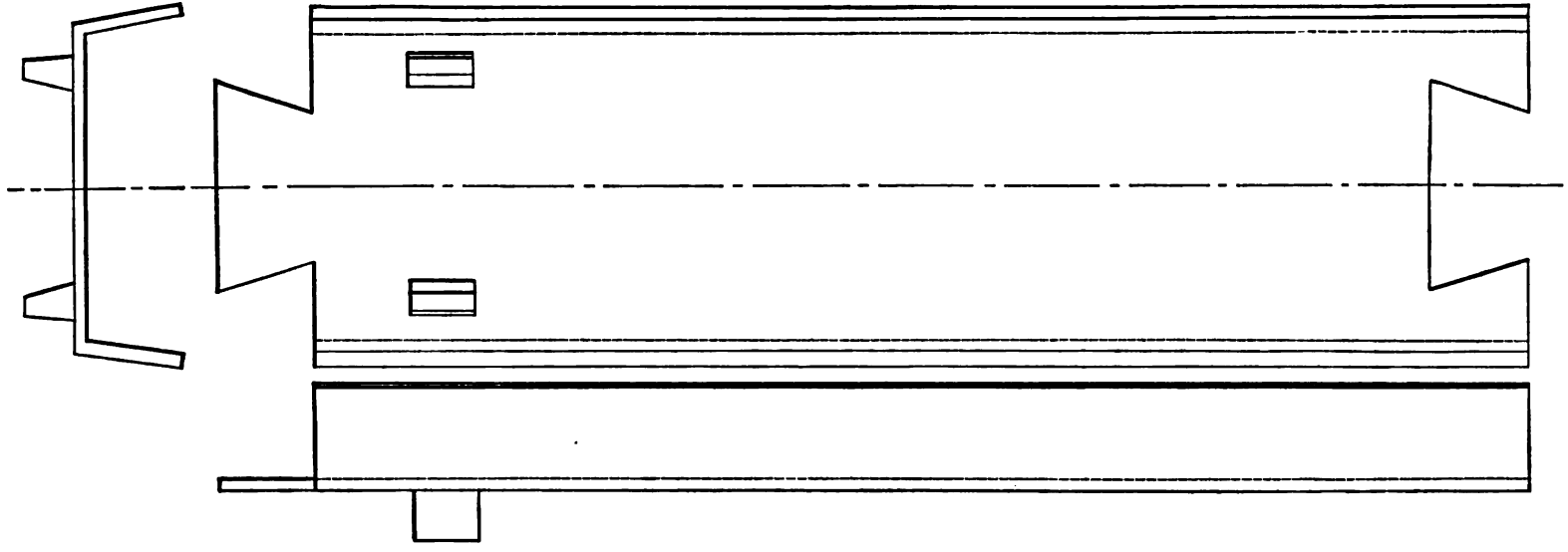
FIG. 7.




Arrangement of Cinder-Trough.

The best distribution, and the minimum loss of gas when lowering the bell, are obtained by having a large charge. Our unit of fuel is 4 gross tons to each charge, divided into 16 barrows. The ore-charge is also divided into 16, and the limestone into 8 barrows. One-fourth of all the stock is filled through the small bell, and by dumping the barrows of the different ores in the charge at different

FIG. 8.



Detail of Cinder-Trough. Plan, and side Section of Plate A, Fig. 7. Scale 1 in.=1 ft.

points in rotation, they are evenly distributed in the furnace. The inside bell is filled by means of stationary runs or skeleton tracks bolted to the hopper. By this arrangement, a definite proportion of the stock is dumped into the small bell. This is preferable to dumping on the crest of an annular bell, as is usually done in other double chargers, such as Mr. Firmstone's improved Langen*, or the Bowman charger, largely used on the Lehigh. That method permits a part of each barrow-load to roll over into the small bell, but leaves the determination of this portion to luck and the top-filler. The Durham bells are operated by a double-acting air-cylinder. The inside bell is first lowered and closed, and then both bells are lowered together (as shown by the drawings), dumping the outside one. The lever of the small bell only is attached to the piston; the large bell is counter-balanced and kept in place by the pressure brought against it by the small bell. When a small bell is to be replaced the new one is made in halves, and these are bolted together after it is in position.

The furnace has but one down-comer E, Fig. 1 (5-foot shell with 4½-inch lining, leaving the diameter 4 feet 3 inches inside) which has given good results. By keeping the gas together, we think it secures a better control and distribution, and more economical results.

There are twelve cylindrical 36-inch boilers KK, Fig. 4, 60 feet long, with 30-inch mud-boilers 40 feet long. They are in sets of three; and since only nine are required to run the engines, pumps, etc., we always have a spare set, and are able to clean boilers every three months. The water is limy; and we have found nothing in the way of anti-incrustators as good as this policy of abundant boiler-power and frequent cleaning.

The Durham hot-blast stoves, designed by Mr. Edward Cooper, have been in almost continuous use since 1876. Figs. 9, 10, 11, 12, and 13, Plate II., show their simple construction. They have no combustion-chamber underneath, but a small chamber at the end, where the gas enters and is ignited, and passes into the oven through slots in the partition-wall, there being one opening between each two rows of pipes, and between the walls and pipes. The flame is carried into the oven and burns among the pipes. The cold-blast enters at the same end with the gas, an arrangement which protects the pipes from being destroyed where the gas is hottest. The gas-openings can be kept clean from the outside through small cleaning-doors,

* *Transactions*, vol. xiii., p. 520.

thus always insuring a uniform distribution of gas, which is not always the case with ovens having a combustion-chamber underneath, with openings that cannot be cleaned while the oven is in use. The bed-pipes are made in small sections, as shown in Figs. 10 and 13. This provides for all expansion, so that leaks are almost an impossibility. The ovens are made in small sections in order to better regulate the heating-surface to the volume of air used at different times. The sections can be made with either three or four rows of pipes, and with seven or eight pipes to each row. Each pipe has 65 square feet of heating-surface; and it has been found at Durham that 100 pipes or 6500 feet of surface will heat 16,000 cubic feet of air (engine-measurement) per minute, and that with regular running 950° to 1000° F. of heat can be maintained. The cost of one 24-pipe oven* is $3650.00; but when built in

---

* *Detailed Cost of one 24-pipe Durham Oven.*

| Castings. | Lbs. | Lbs. |
|---|---|---|
| 24 U-pipes, 14 ft. high, 9 in. outside diam., 7 in. inside, | 2400 | 57,600 |
| 48 sleeves, | 100 | 4,800 |
| 2 end bed-pipes, | 1500 | 3,000 |
| 21 small bed-pipes, | 475 | 9,975 |
| 2 15-inch connections, | 1340 | 2,680 |
| 12 large doors and frames, | 325 | 4,000 |
| 22 small doors and frames, | 82 | 1,804 |
| 4 angle binders, | 620 | 2,480 |
| 2 chimney bases, | 1000 | 2,000 |
| 27 roof frames and lids, | 135 | 3,645 |
| Total, | | 91,984 |

| | | |
|---|---|---|
| 91,984 pounds castings, at 1¾ cts., | | $1699 72 |
| Machine work, | | 50 00 |
| Freights to any reasonably near point, at $1.50 per ton, | | 69 00 |
| 25 M. hard bricks, size made at South Amboy, at $8, | | 200 00 |
| 20 M. 9-inch fire-bricks and shapes, at $26, | | 520 00 |
| Laying 45 M. bricks, including helpers, erecting scaffolds, etc., at $6, | | 270 00 |
| 164 yards 60-pound old rails (9840), at 1 cent, | | 98 40 |
| Two 9-inch beams, 22 feet 10 in. long, Two 9-inch beams, 8 feet long, | 1435 lbs., at 3¼ cts., | 46 64 |
| 423 feet 1¼ inch binder rods, nuts, etc., 2750 lbs., at 2¼ cts., | | 61 87 |
| Two smoke-stacks, 28 feet long, 24 inches diameter, $\frac{3}{16}$-inch iron, 2900 pounds, at 3½ cents, | | 101 50 |
| Two 14-inch jet burners, at $46, | | 92 00 |
| Two 15-inch gate valves, at $55, | | 110 00 |
| Eighty 1-inch bolts and nuts, | | 6 00 |
| Hemlock lumber for scaffolding, | | 25 00 |

double sections, the cost of two 24-pipe sections in one oven is $6869.16, equal to $143.10 for each pipe. Ovens containing a large number of pipes would be somewhat cheaper per pipe, since valves, scaffolding, bolts, etc., would remain the same, or at least would not increase in cost proportionally to the number of pipes. I consider the 24-pipe oven very convenient, and therefore have based my estimate upon it. In designing new plants, a safe rule would be to provide in the stoves one square foot of heating-surface for every two cubic feet (piston displacement) of blast. A furnace making 500 tons of iron weekly would thus require 84 pipes, and the ovens for such a plant, say three 28-pipe ovens, disposed in one double and one single oven, would cost less than $12,000. Two double ovens, giving 112 pipes, would leave an extra section for contingencies. But this, however convenient, is not absolutely necessary.

---

| | | |
|---|---|---|
| Lumber and carpenter work for centers, | | 20 00 |
| Labor, erecting pipes, binders, valves, smoke-stacks, making joints, calking, placing bed-pipes, etc., | | 37 50 |
| Iron borings, | | 6 00 |
| Lime, sand, fire-clay, and kaolin, | | 65 00 |
| Ordinary foundation and excavation, 57 yards, at $4, | | 228 00 |
| Add for contingencies, | | 33 37 |
| Total, | | $3650 00 |

*Building two 24-pipe Sections in one Double Stove, would save:*

| | | |
|---|---|---|
| 15 M. red bricks, | $8 | |
| Laying, | 5 | |
| Lime and sand, | 1 | |
| | $14 | 210 00 |
| Castings: 12 small and 10 large doors and frames, 4200 lbs., at 1¾ cents, | | 73 50 |
| 143 yards rails, | | 85 40 |
| 1110 lbs. 9-inch beams, | | 36 07 |
| 1150 lbs. rods, nuts, etc., | | 25 87 |
| Total, | | $430 84 |
| Two 24-pipe ovens, at $3650.00 = | | 7300 00 |
| Less above, | | 430 84 |
| Cost of double stove with 48 pipes, | | $6869 16 |

If 48 pipes cost $6869.16, one pipe with 65-foot surface would cost $143.10.

NOTE.—In the foregoing estimate, the price of 1¾ cents per pound for castings is the price we are now charging to customers at the Durham foundry. The price of $26 per M. for fire brick is $1.40 more than our fire-brick actually cost us. We purchased Tyrone brick at an exceptionally low figure.

Pequest furnace and Secaucus furnace, N. J., have plants of 28-pipe Durham stoves, and the Andover Iron Works, Phillipsburgh, N. J., and Warwick furnace, Pottstown, Pa., are building Durham stoves.

We use seven Taws & Hartman bronze tuyeres, with 4¼-inch nozzles (aggregating 99.3 square inches). We have found that 1 square inch of nozzle will deliver 157 cubic feet of air per minute or 6 square inches of nozzle for 1000 feet of air, engine-measurement, under the conditions of our last campaign, as stated below. By using this formula a uniform distribution can be had, and the same volume of blast put through each tuyere, making the furnace less liable to drive ahead on any one side than with larger nozzles, half of which might have area enough to deliver all the air used. During our blast just ended, of one hundred and fifty-one weeks, we lost but eleven tuyeres, six of which had been used for a time during a former blast. This is an average loss of one tuyere every ninety-six days.*

The fuel used was Lehigh anthracite and Connellsville coke. The proportion of coke never exceeded 18¾ per cent. Sometimes we used but 12½ per cent. of coke, and occasionally, for short periods, anthracite alone. The ores were ⅛ hematite and ⅞ magnetite. One-half of the magnetic ores were mined from the Durham property, and the other half from Ringwood and Charlotteburg, N. J. During the blast of one hundred and fifty-one weeks, the furnace made 90,450 gross tons of pig iron, being an average of 599 tons weekly. The ore-mixture yielded 53⅓ per cent. of iron, but owing to the siliceous Durham ores it required 59.42 per cent. of limestone, or 2495 pounds to the ton of pig iron. The fuel per ton of iron was 1 ton, 4 cwt., 2 quarters, 10 pounds (2765 pounds) throughout the blast, including

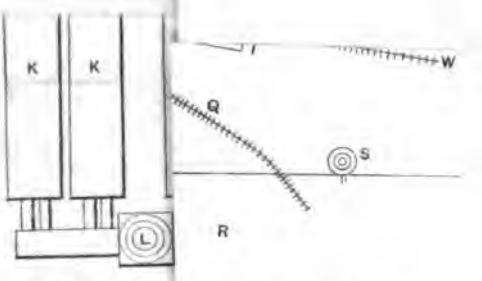
* The tuyeres lost during the blast commencing April 1, 1882, were as follows:

| | Position. |
|---|---|
| 1882, October 28th, | No. 7 |
| " November 10th, | " 5 |
| " December 16th, | " 3 |
| 1883, September 25th, | " 1 |
| " December 29th, | " 6 |
| 1884, June 8th, | " 7 |
| " June 28th, | " 5 |
| " July 24th, | " 4 |
| " October 14th, | " 2 |
| " October 19th, | " 6 |
| 1885, January 14th, | " 2 |

Total, eleven tuyeres lost, viz.: Nos. 1, 3, and 4, once each, and Nos. 2, 5, 6, and 7, twice each.

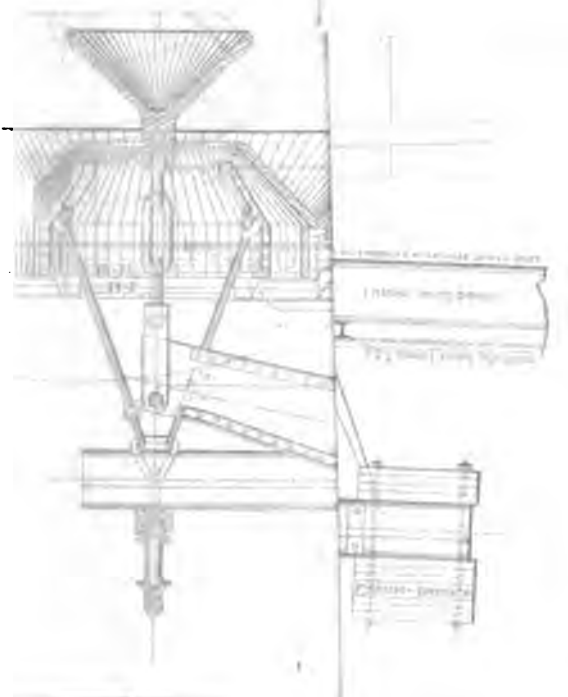
| | | For Blast of 151 Weeks. | | For 2 years, ending Dec. 31, 1884. | | For 1 year, ending Dec. 31, 1884. | | For 6 months, ending Dec. 31, 1884. | | For June, 1884. | | For October, 1884. | | For November, 1884. | | For December, 1884. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tons. | Per ct. | Tons. | Per ct. | Tons. | Per ct. | Tons. | Per ct. | Tons. | Per ct. | Tons. | Per ct. | Tons. | Per ct. | Tons. | Per ct. |
| Pig-iron Product. | No. 2X, | 4,069.5 | 4.33 | 3,256.5 | 5.09 | 1,464.5 | 4.49 | 911.0 | 5.44 | 51.0 | 1.77 | 66.5 | 2.35 | 371.5 | 12.94 | 257.0 | 8.86 |
| | No. 2, | 20,782.5 | 22.91 | 15,560.0 | 24.32 | 7,376.0 | 22.63 | 3,543.0 | 21.16 | 432.5 | 14.97 | 346.0 | 12.24 | 1,383.5 | 48.21 | 949.0 | 32.73 |
| | Gray forge, | 59,103.0 | 65.57 | 40,378.0 | 63.10 | 21,526.5 | 66.05 | 10,723.5 | 64.03 | 2,398.5 | 83.26 | 2,413.5 | 85.41 | 992.5 | 34.59 | 1,647.0 | 56.77 |
| | Mottled, | 6,075.0 | 6.77 | 4,502.5 | 7.04 | 2,105.0 | 6.46 | 1,447.5 | 8.66 | ..... | ..... | ..... | ..... | 122.5 | 4.26 | 47.5 | 1.64 |
| | White, | 420.0 | 0.42 | 285.0 | 0.45 | 120.0 | 0.37 | 120.0 | 0.71 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Total, | 90,450.0 | 100.00 | 63,982.0 | 100.00 | 32,592.0 | 100.00 | 16,745.0 | 100.00 | 2,882.0 | 100.00 | 2,826.0 | 100.00 | 2,870.0 | 100.00 | 2,901.0 | 100.00 |
| | Weekly average, | 599.0 | ..... | 612.4 | ..... | 623.4 | ..... | 637.0 | ..... | 672.5 | ..... | 638.1 | ..... | 669.7 | ..... | 655.1 | ..... |
| | Daily average, | 85.5 | ..... | 87.5 | ..... | 98.1 | ..... | 91.0 | ..... | 96.1 | ..... | 91.2 | ..... | 95.7 | ..... | 93.6 | ..... |
| Total fuel, tons, | | 111,284.75 | | 78,591.25 | | 40,530.25 | | 21,218.25 | | 3,248.0 | | 3,520.0 | | 3,568.0 | | 3,608.0 | |
| Fuel per ton of iron, tons, | | 1.228 | | 1.227 | | 1.243 | | 1.269 | | 1.127 | | 1.245 | | 1.243 | | 1.244 | |
| Total ore, tons, | | 169,575.7 | | 119,925.9 | | 61,325.3 | | 31,287.1 | | 5,140.2 | | 5,280.0 | | 5,352.0 | | 5,523.8 | |
| Ore per ton of iron,* tons, | | 1.875 | | 1.874 | | 1.882 | | 1.868 | | 1.783 | | 1.869 | | 1.864 | | 1.904 | |
| Yield of ore per cent.,* | | 53.33 | | 53.35 | | 53.14 | | 53.52 | | 56.06 | | 53.52 | | 53.62 | | 52.52 | |
| Total limestone, tons, | | 100,755.1 | | 71,537.95 | | 36,543.6 | | 18,628.2 | | 3,057.3 | | 3,124.0 | | 3,166.6 | | 3,272.95 | |
| Limestone per ton iron, tons, | | 1.114 | | 1.118 | | 1.121 | | 1.112 | | 1.061 | | 1.105 | | 1.103 | | 1.128 | |
| Limestone per cent. of ore, | | 59.42 | | 59.65 | | 59.59 | | 59.54 | | 59.47 | | 59.16 | | 59.16 | | 59.23 | |
| Blast, average cu. ft. per min., | | 15,618. | | 15,700. | | 15,763. | | 15,763. | | 15,700. | | 15,885. | | 16,011. | | 15,700. | |
| Average pressure, lbs., | | 9.6 | | 9.6 | | 9.333 | | 9.0 | | 9.625 | | 9.0 | | 9.0 | | 9.111 | |
| Temperature, F., | | 960.° | | 949.° | | 951.° | | 960.° | | 970.° | | 931.° | | 930.° | | 960.° | |
| Unusual stops, hours, | | 435.0 | | 312.5 | | 155.0 | | 53.25 | | 14.25 | | 10.25 | | 3.5 | | 5.75 | |

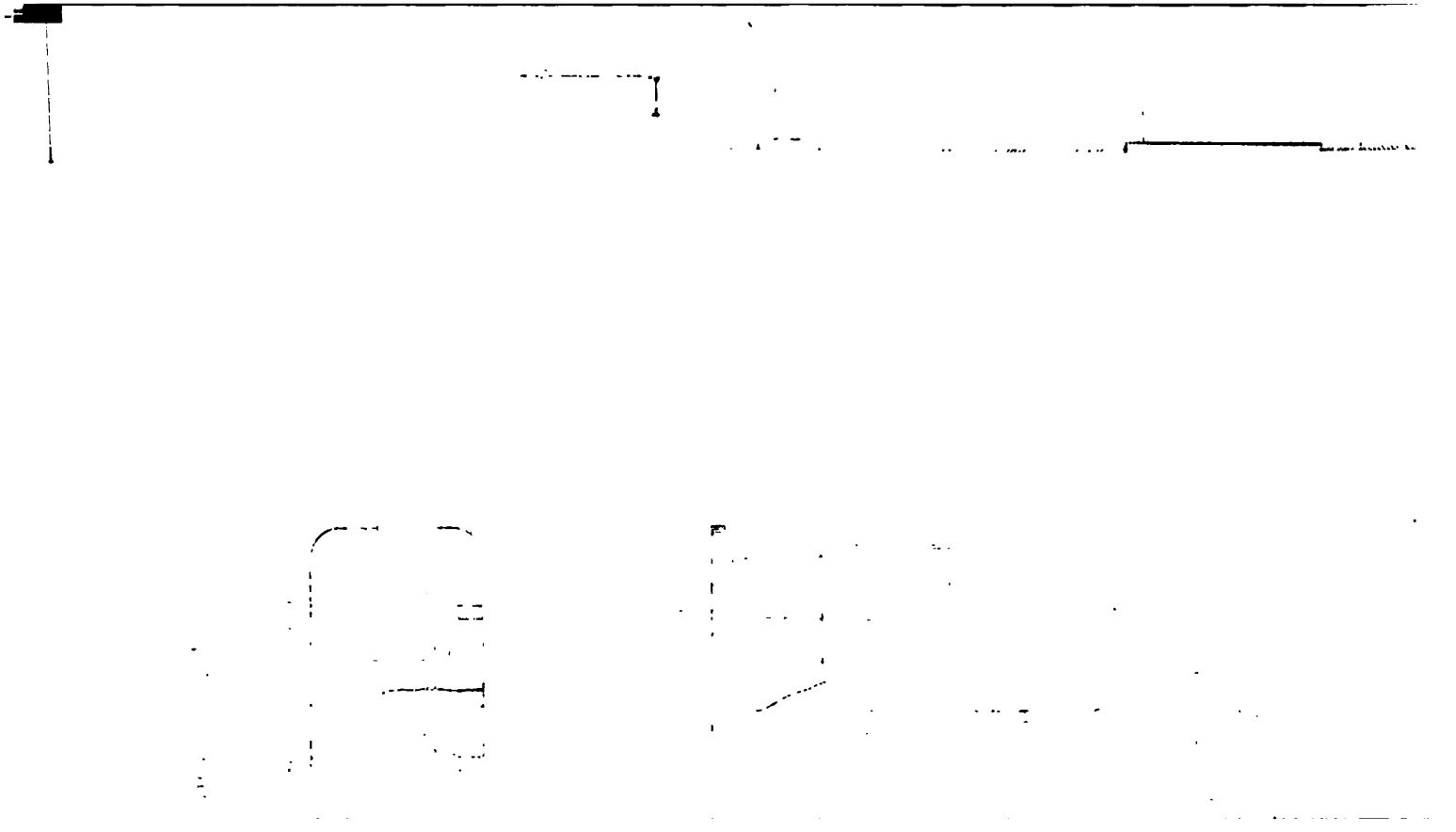
* In this calculation 350 tons of scrap, charged during the blast (besides the ordinary scrap of the casting-house) is not considered. If this scrap be deducted from the pig-iron product, we have 90,100 tons pig; or a yield of the ore of 53.13 per cent. If the scrap be added to the ore, on the other hand, we have 169,925.7 tons mixture charged, yielding 53.23 per cent




Sketch, show… g-house; D, stock-house; E,
tank for tuyere-w… M, engine-house; N, engine
and dynamo for e… upola; T, runner for cinder
from cast; U, U, …

*b*, lugs;





blowing-in week. The temperature of the blast averaged 960° F., and it was found that 88.76 cubic feet of air, piston-displacement, was required to consume 1 pound of fuel. There was a marked regularity in the blast-pressure, the average for the blast being 9⅜ pounds, while the lowest for any one month was 9 pounds. The blast was supplied by two Henry G. Morris upright engines, 4-foot stroke by 7-foot air-cylinders, which have been found entirely too small for the capacity of the furnace; at no time have we been able to run them over 26 revolutions, which fixed the limit of air at 16,000 cubic feet per minute piston-displacement; the air actually blown averaged 15,618 cubic feet per minute piston-displacement, showing that the work was limited by insufficient blowing-engines.

The unusual stoppages for the blast amounted to 435 hours, the greater part of which was required by repairs to the engines.

The regularity of the working of the furnace will appear from the foregoing table.

The lowest fuel-consumption for the period of a year was 1.203 tons; for six months, 1.188 tons; for one month, 1.109 tons; and for one week, 1.05 tons, per ton of pig. The largest week's product was 701 tons; the second, 700 tons.

---

## *FURTHER NOTES ON THE CLAPP AND GRIFFITHS PROCESS.*

BY ROBERT W. HUNT, TROY, N. Y.

DELAYS in the completion of the alterations to the plant at the works of Messrs. Oliver Bros. and Phillips, in Pittsburgh, coupled with the increased demand for metal made from regular Bessemer pig, placing the firm many hundreds of tons behind in their deliveries, prevented Mr. Henry W. Oliver, Jr., from redeeming his promise to place his works at my disposal for further tests of high-phosphorus irons, until May 5th. Upon that date, I assumed charge of the operations in his steel-plant. Mr. Oliver had purchased Neshannock pig as a basis for a supply of phosphorus. My information is to the effect that this iron is made from low-grade Lake Superior ores and mill-cinder, the latter "ore" being utilized to about 40 per cent. of the total mixture. At all events the pig had quite as much phosphorus, and in as varying quantities, as the most exacting could desire. My experiments of last fall had well satisfied me as to the effect of from 0.35 to 0.55 per cent. of phosphorus in the Clapp-Griffiths metal. Hence at this time my first trials were directed to

determine the effect, or rather necessary proportions of manganese for both rolling and subsequent results. Remembering the composition of my former experiments, I made my first mixture of 35 per cent. Neshannock and 65 per cent. Stewart, which latter is a regular Western Bessemer iron, made from Lake Superior ores. The mixtures used and the composition of the resulting steel are shown in the following table. The No. 3 Colebrook iron is from Cornwall ore.

It will be observed that I have used the expression "Trace" for the amount of silicon contained in the various heats of steel. Perhaps it would have been better to give an array of decimals, but Mr. Torrance, while in several cases giving them to me, said: "I really do not know how near right these figures may be; for the quantity seems to be about the same, whether or not I double the amount of borings under determination." In determinations of silicon from borings from the same heats, Mr. McCreath reports: silicon, 0.008; 0.004; 0.006; 0.004; 0.009. The atmosphere of Harrisburg is clearer than that of Pittsburgh; and putting all personal considerations aside, we can perhaps safely accept Mr. McCreath's determinations. But the difference between 0.006 and "a trace" is certainly of a discriminating quantity.

| Mixture, percentages. | | | | | | Chemical Analysis of the Resulting Steel. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Neshannock. | Stewart. | Paxton. | Colebrook. | Steel scrap. | C. | P. | Si. | Mn. | S. |
| 1 | 35 | 65 | | | | 0.10 | 0.32 | trace. | 0.63 | 0.03 |
| 2* | 55 | 40 | | | 5 | 0.12 | 0.43 | " | 0 81 | 0.035 |
| 3 | 75 | 20 | | | 5 | 0.12 | 0.55 | " | 0.77 | 0.055 |
| 4* | 55 | 45 | | | | 0.11 | 0.42 | " | 0.54 | undet. |
| 5* | 55 | 45 | | | | undet. | undet. | undet. | 0.68 | " |
| 6* | 75 | 20 | | | 5 | 0.08 | 0.72 | trace. | 0.50 | 0.03 |
| 7* | 75 | 20 | | | 5 | 0.11 | 0.96<br>0.944 | "<br>0.006 | 0.70 | 0.06 |
| 8* | 90 | | | | 10 | 0.13 | 1.13<br>1.071 | trace.<br>0.004 | 0.50 | 0.05 |
| 9* | 90 | | | | 10 | undet. | undet. | undet. | 0.73 | undet. |
| 10 | | | 45 | 55 | | 0.08 | 0.44 | trace. | 0.80 | 0.09 |

* In No. 4 less ferro-manganese was used than in No. 2. No. 5 is the same mixture as No. 4, with more ferro-manganese. Nos. 6 and 7 are the same mixture, more ferro-manganese having been added to No. 7. The relation of Nos. 8 and 9 is similar. In the double determinations of P and S for Nos. 7 and 8, the upper line gives the results obtained by Mr. H. C. Torrance, and the lower line those of Mr. A. S. McCreath.

All of this steel was cast into 8-inch square ingots, and excepting some ingots of each of the three heats of the Paxton mixture (No. 10) was rolled during my visit. Most of it I saw heated and rolled. *It all worked in a practical manner.* In fact, the behavior in rolls illy adapted to its treatment, was a *revelation* and surprise to every one witnessing the trials; and I may interpolate the remark that there were plenty of witnesses. A great quantity of this metal was reduced to $\frac{3}{8}$-inch rounds and manufactured into various commercial products. The results prove that there is no doubt of the possibility of making metal containing at least 1.10 per cent. phosphorus, which will roll well. But it is entirely another question as to the value of such material for general commercial purposes.

These later experiences no doubt confirm all previous ones, that high phosphorus requires high manganese. But I cannot now say definitely the proportions required for the best work. I had blacksmith-tests made of all of the various heats; and since then have received the results of systematic physical tests for tensile strength, elastic limit, elongation, etc.

The following table shows the results of these tests. Since the samples are not in all cases those described above, I introduce the chemical analysis of each:

| Chemical Analysis. | | | | | Physical Tests. | | Elongation, per cent. | Reduction of area, per cent. |
|---|---|---|---|---|---|---|---|---|
| C. | P. | Si. | Mn. | S. | Tensile Strength, lbs. | Elastic Limit, lbs. | | |
| 0 10 | 0.32 | trace. | 0.63 | 0.03 | 79,440 | 58,500 | 24.00 | 47.0 |
| 0.12 | 0.43 | " | 0.81 | 0.035 | 86,230 | 67,150 | 18.75 | 31.8 |
| 0 12 | 0.55 | " | 0.77 | 0.05 | 79,780 | 59,650 | 23.50 | 35.5 |
| 0 31 | 0.40 | " | undet. | undet. | 77,460* | *nil.* | 0.62 | *nil.* |
| 0.08 | 0.72 | " | 0.50 | 0.03 | 75,290 | 69,150 | 2 25 | 2.6 |
| 0.13 | 0.85 | " | 0.73 | undet. | 101,540† | 74,080 | 9.50 | 9.44 |

Most of the ingots made from the mixture of Paxton and Cornwall irons (No. 10) were sent to the Paxton Rolling-Mills at Harris-

* This metal worked beautifully in rolling, and a star-shaped piece of lightning-rod made from it bent double when cold but was very stiff. It again proves that high phosphorus requires low carbon.

† Another test of the same steel, made upon a larger section, gave but 74,234 tensile strength. Steels with 0.96 and 1.071 phosphorus and 0.13 carbon, gave from 78,365 to 82,040 tensile strength, without practical elongation or reduction of area. There were some twenty-five tests made of these extremely high-phosphorus steels, with about the same results. Part of them were made in the Pittsburgh Testing Laboratory, and the others at the Rensselaer Institute in Troy.

burgh, Pa. There were three heats made from those irons, and the steel had phosphorus 0.37, 0.44 and 0.34, the phosphorus in the first and last heats being effected by the regular Bessemer-iron mixture which preceded and followed them in the cupola. Henry McCormick, Esq., the largest owner of the Paxton Mills, writes me (with permission to publish), as follows:

"The Clapp-Griffiths ingots turned up on Thursday. Tried one of each heat; breaking down first into nail-slabs 12 in. × 12 in. × 2 in., then rolling into nail-plate and cutting into nails. Under treatment it behaved like mild Bessemer nail-slabs (only softer) that we have been working. It lost 1 per cent. in weight in heating-furnace from slab to plate (usual loss steel). In nails, it stood the tests of driving as well as average of Bessemer Steel nails made from Pennsylvania Steel Company's, or Homestead (Pittsburgh) slabs. No appreciable difference in samples tried from the three heats. We did not give any extra annealing, but just submitted them to regular treatment. We will go on and try the other ingots next week and roll some tank-plate. If any different behavior develops, will advise you."

As Mr. McCormick has not "advised" me, I presume his subsequent tests gave similar results.

During the time I was at the works of Messrs. Oliver Bros. & Phillips I saw some one hundred and thirty or more heats of steel made from their regular mixture of iron. Most of these I also saw rolled both from the ingots into billets and from the billets into subsequent commercial products. The greater proportion was reduced from 8-inch ingots into billets on a 20-inch muck-bar train, using the regular gothic grooves; the remainder on a 16-inch mill. I can only say that I never saw soft steel roll equal to it. And I think the many steel experts who witnessed with me the rolling of this metal will indorse my statement. From the steel alluded to I did not see a *single cracked ingot*—I cannot say *bloom*, because the ingots are at once rolled into billets, and even in the highest phosphorus stuff, as the ingot became reduced to billets the cracks either pulled out, closed up, or disappeared in some other manner to an extent beyond anticipation.

I am informed by one of the best-known makers of iron boiler-plates that they have tested Clapp-Griffiths ingots made at Messrs. Oliver's plant, from a low-phosphorus mixture, breaking them down into plates on their iron boiler-plate train, which they accomplished without any difficulty, this being the opposite from their experience

with steel obtained from other parties and made by a different process. The resulting plate they had tested for elongation, reduction, etc., and by heating it, quenching in water, and then bending over flat against the grain; and also submitted it to the severest flanging tests. In all respects it was equal to any open-hearth steel they had ever seen. This was confirmed by the opinion of one of the oldest and most celebrated mechanical engineers of Philadelphia, in whose shops the flanging-tests were made.

I had several samples of metal taken from the converter at different periods of the blow, getting the following results:

| | Silicon. |
|---|---|
| Before pouring into converter, | 1.68 |
| In five minutes, while slag was running from slag-tap, | 0.42 |
| Three minutes later, | 0 09 |
| At finish, before addition of ferro-manganese, | 0.0023 |
| Total length of blow, 13½ minutes. | |

Another heat gave:

| | Silicon. |
|---|---|
| Before pouring into converter, | 1.50 |
| At end of flow of slag, 7½ minutes, | 0.16 |
| Three minutes later, | 0.06 |
| At finish, before addition of ferro, | trace. |
| Total time of blow, 12 minutes. | |

Another test gave:

| | Silicon. |
|---|---|
| Before pouring into converter, | 2.01 |
| Two minutes, or soon as possible after the metal covered the tuyeres, | 2.18 |
| Two minutes later, | 1.78 |

This last test proves that iron is burnt at the very commencement, and also seems to confirm the theory that it serves to form a base for the washing away of part of the silicon of the bath.

In a test of like kind, in a regular 4-ton Bessemer converter and with a full charge of iron under treatment, the following results have been given to me:

| | First Test. | Second Test. |
|---|---|---|
| Silicon in metal, | 2.384 | 2.394 |
| At end of 8 minutes, | 1.07 | 1.10 |
| At end of 15 minutes, | 0.108 | 0.107 |
| At end of 17 minutes, | 0.058 | 0.056 |
| End of blow, 18 minutes, | 0.037 | 0 043 |

Since then I have had two similar tests made at the Troy Bessemer Works. Mr. C. T. Arnberg, superintendent of that department,

exercised great care in carrying out my wishes. The chemical determinations were made by Mr. J. M. Sherrerd, the chemist of the works.

| | First Tests. | | Second Tests. |
|---|---|---|---|
| Silicon in metal, | 1.97 | | 1.87 |
| End of 6 minutes, | 0.815 | | 0.486 |
| End of 10 minutes, | 0.298 | | 0.052 |
| End of 12½ minutes, | 0.073 | End of 11½ min. (end blow), | .... |
| End of 15 min. (end blow), | 0.011 | After addition of ferro, | 0.018 |
| After addition of ferro, | 0.014 | Carbon in steel, | 0.14 |
| Carbon in steel, | 0.14 | | |

The sample taken at the end of blow of the second test had so much cinder mixed through it that a satisfactory determination of silicon could not be made. The first heat had 17,000 pounds, and the second 16,500 pounds of metal under treatment. The first experiments, in both the Clapp-Griffiths and Troy Bessemer converters, were taken from the first heats on the vessel bottoms. It will be observed that the blows were longer and the elimination of silicon slower than in the second heats. In neither case at Troy was the elimination of silicon as complete as in the two Clapp-Griffiths tests.

The practically total elimination of silicon in the Clapp-Griffiths process is certain every time, and without at all depending upon any skill or care on the part of the workman having the heat in charge. Low silicon has been and is still made in the ordinary Bessemer converter, and I congratulate my Bessemer brethren upon the results they have obtained. But I must still hold to the opinion that the result is not a certain thing: that is, the heats will sometimes give disappointing results.

I have had a number of analyses of steel nails made, taking the samples from those in stock at various stores and of several brands, and while generally very low in silicon, specimens have turned up to the extent of 28 per cent. of the analysis made, which have not been so low, and some have run as high as 0.044 per cent. silicon. The heat from which these nails were made no doubt escaped the notice of the metallurgist in charge of the works. Perhaps I was particularly unfortunate in my selection of samples.

From a long acquaintance with the working of Messrs. Oliver Bros. & Phillips' Clapp-Griffiths plant, I am confirmed in all I have previously said in relation to quantity of output and cost of production. As to the use of high-phosphorus irons, I am fully convinced that for nails and many other purposes steel can be used to advantage

which contains up to 0.55 per cent. of phosphorus. I do not think a metal with so great an amount of phosphorus would answer to put on the market for general purposes; but where it is to be manufactured into specialties to which it is adapted, it can be profitably used. I can assure the Institute that I saw some very surprising results in the working up of the high-phosphorus steel made by me during these last trials. As before stated, it was all utilized.

With low-phosphorus irons the very best results for the highest purposes can be obtained; and working from that point up, each manufacturer can determine for himself what irons he can use.

I am fully convinced by longer study of the process that low silicon does not alone account for the extremely good quality of th Clapp-Griffiths metal. Large volumes of blast at low pressure, the tapping off of the slag, and presence of oxide of iron during the process, all play an important part. After having experimented to produce similar metal in a regular Bessemer converter, I am fully satisfied that considerations of first cost of construction, quality and certainty of metal produced, and cost of production favor the adoption of the Clapp-Griffiths converter for general soft metal products, especially where the circumstances demand the substitution of steel for iron in a plant already built. Moreover I shall be much surprised if the developments of the next few months do not place the process upon a footing in relation to phosphorus which has not yet been claimed for it.

I have to thank Mr. George E. Tener, Mr. H. C. Torrence, Mr. George W. Brian, Mr. Evans, in fact every one connected with the Messrs. Oliver's works with whom I came in contact, for their kind and intelligent assistance in my experiments.

## Discussion.

P. G. Salom, Philadelphia, Pa. (communication to the Secretary): I have watched with the greatest interest the development of the Clapp-Griffiths process in this country, and notwithstanding the unfavorable comments that have been passed upon it by some of the metallurgical savants of the day, I look upon it as the beginning of a successful revolution against the primitive and barbarous method of puddling, and as inaugurating the most important epoch in the history of iron since the advent of the Bessemer process. It is interesting and instructive to observe, that the aim of the Clapp-Griffiths process is to accomplish the same result that Bessemer

attempted thirty years ago. Bessemer's idea, and the one that came very near wrecking him and thus depriving the world for a time, at least, of his invaluable discovery, was to produce cast wrought-iron. The introduction of spiegel was only an after-thought, or, rather, an after-necessity, which saved the whole process from annihilation. The Clapp-Griffiths process has succeeded, in a measure, in overcoming the difficulties that Bessemer experienced:

1st. By a different construction of the converter;

2d. By the introduction of ferro-manganese instead of spiegel;

3d. By a partial removal of the slag; and

4th. By the introduction of what might be termed a new principle—the change in position and character of the tuyeres, involving as it does a different chemical reaction in the converter.

It will not do, therefore, for the Bessemer men to sneer at their little antagonist. The fact remains that the Bessemer men have never done anything towards the solution of the problem of avoiding puddling, and that while the results that Mr. Hunt has published do not show that high-phosphorus pig can be converted into the best iron, a result which we have no right to expect, they do show that steel containing as much as 0.3 per cent. of phosphorus can be made to give an elongation of 24 per cent., which must be admitted to be an excellent and surprising result. Moreover, we must remember that puddled iron made from very high-phosphorus pig has no ductility or elongation worth speaking of, and breaks off about as short as pig-iron.

The tests also show that steel with 0.5 per cent. of phosphorus has been made with an elongation of 9 per cent. This is certainly an admirable result, and it only remains to accomplish the same result with every "blow," to insure a complete success.

---

## *THE FLOW OF AIR AND OTHER GASES.*

BY FRED. W. GORDON, PHILADELPHIA, PA.

It is my purpose to call attention to the close approximate correctness of certain coefficients and formulas concerning the flow of gases, and their applicability to the practical construction of flues and

pipes, so as to avoid on the one hand the undue restriction, by bad form or insufficient size, of the conducting areas, and on the other hand the waste of money in excessive sizes.

Draft is an exceedingly tender thing to deal with. Its total head in the gas-flues of a blast-furnace plant hardly ever exceeds 1¼ inches of water; and the immense quantities of waste gases escaping to the atmosphere in blast-furnace practice, being nearly equal to 15 tons to every ton of iron made, require expensive construction, even with the best knowledge of form and size. On the other hand, the five to six tons of blast, introduced into the furnace, for each ton of iron made, require conduits of considerable size, and it is highly important to fix a minimum of size under restricted conditions of form, and to know the effect of modifications.

The remodeling of the Isabella Furnaces at Pittsburgh, in 1880, was undertaken with a view of increasing the then product of 75 tons per day each furnace to 200 tons.

Their air-hoist (Fig. 1) was designed, no doubt, for an ultimate duty of 100 tons per day, and it was to determine the possibility of increasing the power of this hoist that the following experiments were made.

In the figure A is the cold-blast main, 4 feet in diameter; C, the pipe conveying the blast to the air-cylinder, 5 inches in diameter; D, the air-cylinder, 36 inches in diameter.

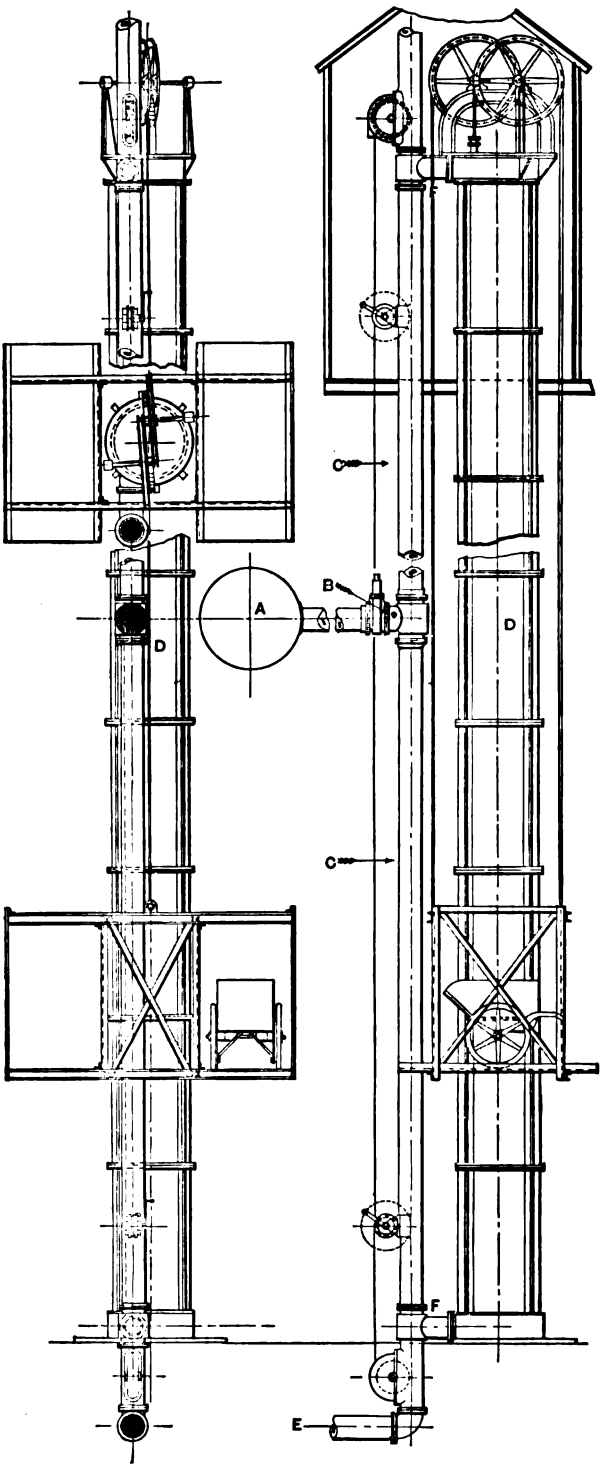
The distance from the main to the connection, B, where a mercurial gauge was placed, was 17 feet; total length of conduit, from A to the cylinder-top, 75 feet; total length of conduit to the cylinder-bottom, 46 feet; average, 60.5 feet.

Time was taken by a seconds-pendulum, the distance marked for time-measurements being 70 feet 6 inches. The temperature of the blast in main A was 110° F.; in cylinder, 60° F.

When the piston was on top and the cage on the bottom, 600 pounds on the cage were required to balance; and when the cage was on the top 1280 pounds were required; demonstrating that the rope removed from the inside to the outside of the cylinder, weighed 340 pounds, and that the carriage when empty weighed 940 pounds less than the piston.

The average friction marked in the table is the total dead weight required to effect the average motion of the experiments within the brackets, and was calculated by deducting the load, plus the counter-resistance, from the head pressure. Though the friction was very small, the piston was tight.

FIG. 1.




Air-Hoist at Isabella Furnace.

| Number of Experiment. | Actual weight on car platform.—Pounds. | Seconds occupied in traveling 70′ 6″. | Pressure in cylinder above the piston.—Pounds. | Pressure in cylinder below the piston.—Pounds. | Pressure observed in 5-inch supply pipe at B.—Pounds. | Pressure observed in blast main A.—Pounds. | Direction cage was traveling. D—Descending. U—Ascending. | Average friction in pounds DEAD WEIGHT, being difference between the head pressure and the load plus the counter-resistance. |
|---|---|---|---|---|---|---|---|---|
| 1 | 975 | 22 | $1\frac{3}{4}$ | 2 | 5 | $6\frac{1}{2}$ | D | |
| 2 | " | 27 | $2\frac{3}{16}$ | 2 | $4\frac{3}{4}$ | $6\frac{1}{2}$ | U | |
| 3 | " | 23 | $1\frac{3}{4}$ | 2 | $4\frac{3}{4}$ | $6\frac{1}{8}$ | D | |
| 4 | 830 | 28 | $2\frac{3}{16}$ | $2\frac{1}{4}$ | $4\frac{3}{4}$ | $6\frac{1}{8}$ | U | 296 |
| 5 | " | $18\frac{1}{2}$ | $1\frac{5}{8}$ | 2 | $4\frac{3}{4}$ | 6 | D | |
| 6 | " | 20 | $2\frac{3}{8}$ | $2\frac{1}{4}$ | $4\frac{1}{2}$ | 6 | U | |
| 7 | | | No record taken. | | | | D | |
| 8 | 0 | 18 | 2 | $2\frac{3}{4}$ | $4\frac{3}{4}$ | 6 | U | |
| 9 | 0 | 21 | $1\frac{3}{8}$ | $2\frac{1}{2}$ | $4\frac{3}{4}$ | $5\frac{7}{8}$ | D | |
| 10 | 0 | 18 | $2\frac{1}{8}$ | $2\frac{3}{4}$ | $4\frac{3}{4}$ | $5\frac{7}{8}$ | U | |
| 11 | 0 | 21 | $1\frac{3}{8}$ | $2\frac{3}{4}$ | 5 | $5\frac{7}{8}$ | D | 271 |
| 12 | 0 | 18 | $2\frac{1}{4}$ | $2\frac{3}{4}$ | 5 | 6 | U | |
| 13 | 0 | 20 | $1\frac{3}{8}$ | $2\frac{1}{2}$ | 5 | $6\frac{1}{4}$ | D | |
| 14 | 1630 | 22 | $3\frac{1}{8}$ | 2 | $5\frac{1}{4}$ | $6\frac{5}{16}$ | U | |
| 15 | " | 17 | $2\frac{1}{8}$ | $1\frac{3}{4}$ | 5 | $6\frac{5}{16}$ | D | |
| 16 | " | 22 | $2\frac{7}{8}$ | $1\frac{3}{4}$ | $5\frac{1}{4}$ | $6\frac{3}{8}$ | U | |
| 17 | " | 16 | $2\frac{1}{8}$ | $1\frac{1}{4}$ | 5 | $6\frac{5}{16}$ | D | 312.5 |
| 18 | " | 22 | 3 | 2 | $5\frac{1}{4}$ | $6\frac{3}{8}$ | U | |
| 19 | " | 17 | $2\frac{3}{8}$ | $1\frac{3}{4}$ | 5 | $6\frac{3}{8}$ | D | |
| 20 | 2430 | 24 | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | U | |
| 21 | " | 16 | $2\frac{7}{8}$ | $1\frac{3}{4}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | D | |
| 22 | " | 24 | $3\frac{1}{2}$ | $1\frac{3}{4}$ | $5\frac{3}{4}$ | $6\frac{1}{16}$ | U | 344 |
| 23 | " | 16 | $2\frac{7}{8}$ | $1\frac{5}{8}$ | $5\frac{1}{2}$ | $6\frac{1}{16}$ | D | |
| 24 | 3030 | 26 | $3\frac{7}{8}$ | $1\frac{1}{2}$ | $5\frac{3}{4}$ | $6\frac{1}{4}$ | U | |
| 25 | " | $15\frac{1}{2}$ | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $5\frac{1}{4}$ | $6\frac{3}{8}$ | D | |
| 26 | " | 26 | $3\frac{7}{8}$ | $1\frac{1}{2}$ | 6 | $6\frac{1}{4}$ | U | 281 |
| 27 | " | $15\frac{1}{4}$ | $3\frac{1}{4}$ | $1\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{4}$ | D | |
| 28 | 3430 | 27 | $4\frac{1}{8}$ | $1\frac{1}{4}$ | $5\frac{3}{4}$ | $6\frac{1}{4}$ | U | |
| 29 | " | 15 | $3\frac{3}{8}$ | $1\frac{1}{4}$ | $5\frac{1}{2}$ | $6\frac{1}{16}$ | D | |
| 30 | " | 27 | $4\frac{1}{8}$ | $1\frac{1}{4}$ | $5\frac{3}{4}$ | $6\frac{1}{16}$ | U | 406 |
| 31 | " | 14 | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $5\frac{1}{2}$ | $6\frac{1}{16}$ | D | |
| 32 | 830 | 20 | $2\frac{5}{8}$ | $2\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{4}$ | U | |
| 33 | " | 18 | $1\frac{7}{8}$ | $2\frac{1}{4}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | D | |
| 34 | " | 20 | $2\frac{5}{8}$ | $2\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | U | 250 |
| 35 | " | 17 | $1\frac{7}{8}$ | $2\frac{1}{4}$ | $5\frac{1}{4}$ | $6\frac{3}{8}$ | D | |
| 36 | 400 | 19 | $2\frac{1}{2}$ | $2\frac{3}{4}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | U | |
| 37 | " | $17\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | D | |
| 38 | " | $18\frac{1}{2}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $5\frac{1}{2}$ | $6\frac{3}{8}$ | U | 312 |
| 39 | " | 19 | $1\frac{5}{8}$ | $2\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | D | |
| 40 | 600 | 17 | $2\frac{7}{8}$ | 3 | $6\frac{1}{4}$ | $7\frac{1}{4}$ | U | |
| 41 | " | 17 | 2 | $2\frac{5}{8}$ | 6 | $7\frac{1}{4}$ | D | |
| 42 | " | 17 | $2\frac{1}{8}$ | $2\frac{1}{8}$ | 6 | $7\frac{1}{4}$ | U | |
| 43 | " | 17 | 2 | $2\frac{5}{8}$ | $5\frac{3}{4}$ | $7\frac{1}{8}$ | D | |
| 44 | " | 17 | $2\frac{5}{8}$ | $2\frac{3}{4}$ | 6 | $7\frac{1}{8}$ | U | |
| 45 | " | 17 | $1\frac{7}{8}$ | $2\frac{1}{4}$ | $5\frac{1}{2}$ | $6\frac{1}{8}$ | D | 300 |
| 46 | " | 17 | $2\frac{1}{8}$ | $2\frac{5}{8}$ | $5\frac{1}{2}$ | $6\frac{3}{4}$ | U | |
| 47 | " | 18 | $1\frac{7}{8}$ | $2\frac{5}{8}$ | $5\frac{1}{2}$ | $6\frac{3}{4}$ | D | |
| 48 | " | 18 | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $5\frac{3}{4}$ | 7 | U | |
| 49 | " | 18 | $1\frac{7}{8}$ | $2\frac{5}{8}$ | $5\frac{1}{4}$ | 7 | D | |

The experiments given in detail in the foregoing table may be grouped into one (taking the average, which will give practical correctness), with the following results:

| | | |
|---|---|---|
| Pressure in main, | 6.56 | lbs. per sq. in. |
| Pressure at B, 17 feet from main, | 5.32 | lbs. per sq. in. |
| Pressure at top of cylinder, | 2.896 | lbs. per sq. in. |
| Pressure at bottom of cylinder, | 2.09 | lbs. per sq. in. |
| Average pressure in cylinder, top and bottom, | 2.493 | lbs. per sq. in. |
| Average time for the piston travel of 70 feet 6 inches, | 19.44 | seconds. |
| Speed of piston per second, | 3.63 | feet. |
| Speed of air per second in 5-inch pipe, by ratios of areas of cylinder and pipe, | 188 | feet. |
| Loss of head from main A to point B, | 1.24 | lbs. per sq. in. |
| Loss of head, average top and bottom of cylinder, | 4.067 | lbs. per sq. in. |
| Calculated weight of air in cylinder, per cubic foot, | 0.089 | lb. |
| Calculated weight of air in main, per cubic foot, | 0.1 | lb. |
| Speed of air per second in pipe, corrected by temperature and pressure: $188 \times 0.089 \div 0.1 =$ | 167.3 | lbs. |

To calculate the losses of head, etc., thus determined experimentally, the theoretical head, $\frac{v^2}{2g}$, is multiplied by the following coefficients:

Friction of gas and air over ordinary iron pipes and smoothly-laid brick-work, $0.02 \times \frac{L}{M}$, L being the length of the pipe in feet, and M its hydraulic depth, or the area divided by the perimeter (for circular pipes, $\frac{1}{4}$ the diameter) in feet.

For right-angle bends, 1.0.

For curved bends with the center-line radius equal to the diameter or depth of flow, 0.4, rapidly decreasing as the bend increases.

For double sharp returns, when in the same direction, the same as single, viz.: 1.0.

For double returns, reversed, double the coefficients of single returns.

For friction of entrance, square edges, 0.6.

For friction of entrance, round edges, from 0.4 to 0.

To calculate the loss of head in any part of this system, the theoretical head is multiplied by the respective coefficients for bends, friction, etc., and the result, $h$, is the loss of head in feet of a column of air at the density of the air in the conduit.

Thus for the short 5-inch pipe from A to B, the length of which

is 17 feet, and the hydraulic mean depth (¼ diameter) 0.104 feet, and in which we allow 0.6 for entrance-friction and 0.4 for form of valve (total, 1.0, besides the ordinary friction in the pipe), and the velocity being 167.3 feet per second, we have:

$$h = \frac{v^2}{2g}\left(1 + \frac{0.02 \times L}{M}\right) = \frac{(167.3)^2}{64.4}\left(1 + \frac{0.02 \times 17}{0.104}\right) = 1853 \text{ ft.}$$

Since the calculated weight of the air in the main is 0.1 pound per cubic foot, it is evident that $\frac{0.1}{144}\,h$ is the loss of pressure per square inch. Hence $1853 \times 0.1 \div 144 = 1.3$ pounds per square inch, the loss of pressure.

The actual observed average loss of pressure, as given in the table above, was $6.56 - 5.32 = 1.24$ pounds per square inch.

Applying the same formula, we calculate the loss of head from the main, A, to the cylinder:

$$h = \frac{(167.3)^2}{64.4}\left(3 + \frac{0.02 \times 60.5}{0.104}\right) = 434\left(3 + \frac{1.21}{0.104}\right) = 6351. \text{ ft.}$$

and $6351. \times 0.1 \div 144 = 4.4$ pounds per square inch. The actual average loss in this case was 4.067 pounds.

The calculation gives, in both these cases, somewhat higher results than the average of experiments. This is explained when we remember that after each test the cylinder gathered considerable heat from the atmosphere, and, owing to its great size, this heat was almost immediately imparted to the incoming air; hence the air-velocity calculated by the measurement of the cylinder was too high, as the air was more condensed while passing through the pipe than the temperature taken from the cylinder would indicate. Making a reasonable allowance for this, the calculation is very close to the actual average.

Fig. 2 is a diagram of the piping of a blast-furnace, constructed in 1880. The upper part is the plan, and below is the corresponding elevation. A, A, are the hot-blast stoves; B is the furnace; C, the chimney; D, gas-flue; E, cold-main, 4 feet in diameter, 78 feet long; E′, cold-main, 2½ feet in diameter, 72 feet long; F, hot-main, 17 inches in diameter, with one 45° bend; G, bustle-pipe; H, flue to chimney; J, J, blowing engines; K, down-pipe, 1.33 feet in diameter, 14 feet long, with bend on bottom; L, tuyere-pipe; N, hot-blast valve, 17 inches in diameter, containing two right-angle bends.

From stove A1, hot-main and hot-blast valve have a total length to bustle-pipe of 26 feet. From the bustle-pipe to the nearest tuyere

is 4 feet, and half-bend from hot-main; diameter, 17 inches. There are seven tuyere-pipes, 8 inches in diameter, 7 feet long. The engines are nominally blowing 13,000 feet of blast per minute. This

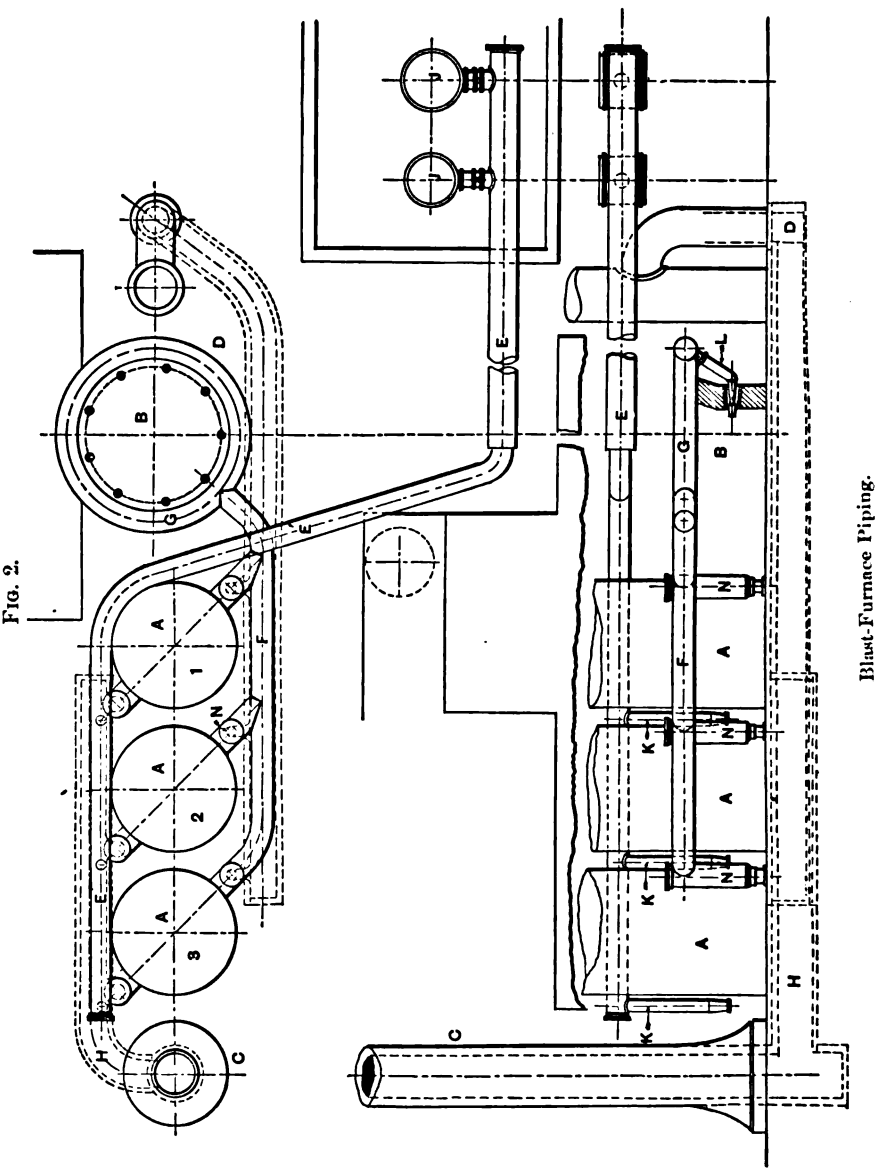



FIG. 2.

Blast-Furnace Piping.

we reduce by 10 per cent. for the waste of the engines, making the volume per second 195 feet. The observed pressures and temperatures are as follows:

| | |
|---|---|
| Pressure in engine-house, | 4.6 lbs per sq. in. |
| Pressure leaving stove, | 4.1 lbs. per sq. in. |
| Pressure in bustle-pipe, | 3.1 lbs. per sq. in. |
| Pressure in tuyere-pipe at eyesight, | 2.75 lbs. per sq. in. |
| Temperature of cold-main, | 100° F. |
| Temperature of hot-main, | 1240° F. |
| Weight of air in cold-main, per cubic foot, | 0.091 lb. |
| Weight of air in hot-main, per cubic foot, | 0.03 lb. |

Multiplying the volume per second of atmospheric air passed through the engine by 0.076, its weight per cubic foot, and dividing by 0.091, we have the actual volume passing per second through main E: $195 \times 0.076 \div 0.091 = 163$ cubic feet per second; and this divided by area of pipe $12.5 = 13$, the velocity in feet per second.

For the 4-foot section E, $h = \frac{(13)^2}{64.4}\left(\frac{0.02 \times 78}{1}\right) = 4.09$ loss of head.

For the $2\frac{1}{2}$-foot section, E′, the area being 4.9 square feet and the velocity 33.2 feet per second, $h = \frac{(33.2)^2}{64.4}\left(0.4 + \frac{0.02 \times 72}{0.625}\right)$ $= 46.17$ feet loss of head.

For the down-pipe, the area being 1.4 square feet, and the velocity 116 feet, $h = \frac{(116)^2}{64.4}\left(1.5 + \frac{0.02 \times 14}{0.33}\right) = 491.15$ feet loss of head.

(The coefficient 1.5 in the above equation is made up of 0.6 entrance to pipe, 0.4 for bend, and 0.5 for increased velocity.)

The hot-blast friction will not be calculated here. Its observed friction was 0.12 pound per square inch, including the entrance- and leaving-resistances. Summing the cold-blast loss of head, we have $4.08 + 46.17 + 491.15 = 541.40$, which $541.40 \times 0.91 \div 144 = 0.342$ pound per square inch, to which we add the observed stove-friction $= 0.12$, giving a total of 0.462 pound per square inch. That actually observed was $4.6 - 4.1 = 0.5$ pound.

For the hot-main, from stove to blast-pipe, the loss is similarly calculated: Volume $195 \times 0.076 \div 0.03 = 494$ cubic feet; which divided by area gives the velocity, 310 feet per second. Hence, $h = \frac{(310)^2}{64.4}\left(2.25 + \frac{0.02 \times 26}{0.35}\right)$ 5595 feet loss of head.

(In this formula, the coefficient $2.25 = 1$ for each right-angle bend, and .25 for the 45° bend) and $5595 \times .03 \div 144 = 1.16$

pounds per square inch, loss of pressure. That observed was 4.1 — 3.1 = 1 pound.

For the tuyere-stock, 7 feet by 8 inches, we have a velocity of 203 feet per second; and $h = \frac{(203)^2}{64.4}\left(1 + \frac{0.02 \times 7}{0.166}\right) = 1152$ feet.

(The coefficient 1 here consists of 0.4 for bend in bustle-pipe, and 0.6 entrance to tuyere-stock.)

$1152 \times .03 \div 144 = 0.24$ pound per square inch loss of pressure in bend in bustle-pipe and in the tuyere-stock. Actual observed loss, 0.35 pound per square inch.

Recapitulating the totals, we have:

| | Calculated. | Actual. |
|---|---|---|
| Cold-main and stove, . . . . | 0.462 | 0.50 |
| Hot-main and valve, . . . . | 1.16 | 1.00 |
| Tuyere-stock, . . . . . | .24 | .35 |
| | 1.862 | 1.85 |

The totals are a very close approximation—much closer than the detail. This is partly accounted for in this way: two of the points where the pressure was taken were critical points of friction, and the friction observed was not fairly distributed in charging it to different parts of the apparatus.

The above examples will fully serve to explain the use of the coefficients and their correctness. Though no other cases are here given, many more observations have been compared with the formulas to establish their correctness.

The friction in the stove was not estimated, as in no case have the observations of the blast been sufficiently close to establish data of practical importance, for estimating the loss of head when on gas. The resistance to the blast is so small as to be of little moment in practice, yet this same friction on draft is of the utmost importance.

To establish this correctly, the volume of gas passing through one of these stoves (see Fig. 3, in Mr. Strobel's paper on the improved Whitwell-Cowper Stove, read at this meeting) was attempted to be determined when it was doing its utmost, by measuring the air-flow and analyzing the inflowing and escaping gases. The observations were, however, quite unsatisfactory. The flow of gas must, therefore, be approximated by knowing the analysis, calculating the heat developed by its practical combustion, comparing this with the heat carried away by the blast as a correction, and accurately observing the draft-head at various points during known duty, measured by the blast-heat.

A plant of stoves, 20 feet diameter and 60 feet high, was carefully observed for many days with this object in view, and reducing these observations to a practical standard, they were as follows:

| | |
|---|---|
| Blast-heat to furnace, . . . . | 1420° F. |
| Blast-heat to stove, . . . . | 100° F. |
| Average temperature of escaping gases, . | 560° F. |
| Average temperature of entering gases, . | 480° F. |
| Temperature of atmosphere, . . . | 50° F. |
| Average composition of gases by volume, | $CO_2$, 8.8; CO, 27. |
| Average composition of gases by weight, | $CO_2$, 13.44; CO, 26.25; N, 60.31. |

The possible calories from the combustion of this composition of gas with the atmospheric air under the above conditions are calculated thus: There being 11.25 pounds of C present as CO in each 100 pounds of this gas, 15 pounds of oxygen, or 65.2 pounds of air will be theoretically required to consume it; and the total weight of gas after combustion will be 165.2, and the temperature given to it by the combustion will be $\frac{11.25 \times 5600}{.24 \times 165.2} = 1589°$ C., or 2892° F. Adding the average initial temperature of the gas and air,* viz.: $\frac{(480 \times 100) + (50 \times 65.2)}{100 + 65.2} = 310°$, and deducting 560°, the average temperature of escaping gases, we have 2642°, which is given off to the stove brick-work. This is equivalent to 1451° C., or $1451 \times 0.24 \times 165.2 = 57{,}529$ centigrade heat-units. But this is not all retained. Perhaps a fair estimate would be 10 per cent. radiation during the heating of the stove and the heating of the blast, leaving 2378° or 51,776 H. U. useful effect.

This is under the assumption that accurate proportions of gas and air are employed. Analysis permits us to assume that fully 15 per cent. of the entering gas may pass unburned in moderately good practice without being detected. This consideration would affect the calculation as follows:

Amount of gas entering to supply 11.25 C as CO, 117.65 pounds; amount (15 per cent.) passing unburned, 17.65 pounds; amount of air, as before, 65.2 pounds.

Average temperature of entering gas and air (assuming equal specific heats) $\frac{(480 \times 117.65) + (50 \times 65.2)}{117.65 + 65.2} = \frac{59{,}732}{182.85} = 327°$ F.

Temperature of product of combustion: $\frac{11.25 \times 5600}{0.24 \times 182.85} = \frac{63{,}000}{43.88}$ $= 1436°$ C. $= 2657°$ F.

* Their specific heats are assumed to be equal. The error is of no moment here

Temperature to be absorbed by brickwork or lost in radiation: $2657 + 327 - 560 = 2444°$ F., or, after deducting 10 per cent. for radiation, 2200° F.

The furnace-engines were delivering 24,000 feet per minute, or 1824 pounds of blast. The weight of the gas within the stoves and the weight of blast are inversely proportional to the temperature imparted by the one and received by the other, provided the specific heats were the same. Neglecting these latter, $1824 \times 1320$ (temperature gained by blast) $\div 2200 = 1095$ pounds, the amount of heating gases which should be passing through both stoves, or 547.5 pounds through each per minute, after making all reasonable allowances. The specific weight of these gases is 1.05, from which the volume passing through the stove and the value of head will be calculated.

The stove was 21 feet external diameter and 60 feet high, with other particulars, as per the following table:

| | Area. | Perimeter. | Hydraulic mean depth. | Length. | Average absolute temperature. |
|---|---|---|---|---|---|
| | sq. ft. | feet. | feet. | feet. | F. |
| Combustion-chamber.. | 32. | 26. | 1.26 | 42 | 2700° |
| First down-pass..... | 32.5 | 147.3 | 0.22 | 42 | 2200° |
| Up-pass..... | 23.6 | 161.8 | 0.146 | 42 | 1500° |
| Chimney-pass ..... | 20.8 | 140.5 | 0.148 | 42 | 1200° |

The temperatures here given are close approximations, from a large number of observations.

From the above it is calculated that 116 cubic feet of gas at ordinary atmospheric tension and temperature, was passing through each stove per second. The velocities in feet per second, at the above temperature and areas, are, therefore:

Combustion-chamber, . . . . . 21
Up-pass, . . . . . 16
First down-pass, . . . . . 17
Chimney-pass, . . . . . 14.4

And the loss of head, $h$, in each pass is, by the formulas already given:

Combustion-chamber, . . $\frac{(21)^2}{64.4}\left(1+\frac{0.02\times 42}{1.26}\right) = 11.4$ feet.

First down-pass, . . . . $\frac{(17)^2}{64.4}\left(1+\frac{0.02\times 42}{0.22}\right) = 22.4$ feet.

Up-pass, . . . . . $\frac{(16)^2}{64.4}\left(1+\frac{0.02\times 42}{0.146}\right) = 28.9$ feet.

Chimney-pass, . . . . . $\frac{(14.4)^2}{64.4}\left(1+\frac{0.02\times 42}{0.148}\right) = 21.5$ feet.

The weight per square foot of each column of gas at the temperatures given, multiplied by the loss of head on each, gives:

| | |
|---|---|
| For the column at 2700°, . . . . | $0.0175 \times 11.4 = 0.1995$ |
| For the column at 2200°, . . . . | $0.0215 \times 22.4 = 0.4160$ |
| For the column at 1500°, . . . . | $0.0315 \times 28.9 = 0.9104$ |
| For the column at 1200°, . . . . | $0.0394 \times 21.5 = 0.8471$ |
| Loss of head in pounds, per square foot, due to flow within the stove, . . . . | 2.373 |

There are, however, two upward currents hotter than the two downward currents, which gives a static head equal to .5 pound per square foot; thus, by calculation:

| | | |
|---|---|---|
| Upward currents, or positive head, . . . | $42\ (0.076 - 0.0175) = 2.457$<br>$42\ (0.076 - 0.0315) = 1.869$ | |
| Total, . . . . . | | 4.326 |
| Downward currents, or negative head, . . | $42\ (0.076 \times 0.0215) = 2\ 289$<br>$42\ (0.076 \times 0.0394) = 1.537$ | |
| Total, . . . . . | | 3.826 |

| | |
|---|---|
| Loss of head due to flow within the stove, . | 2.373 |
| Plus negative head, . . . . . | 3.826 |
| Total resistance, . . . . . | 6.199 |
| Minus positive head, . . . . . | 4.326 |
| The total loss of head within the stove, in pounds per square foot, . . . . | 1.873 |

This is equal to 0.36 of an inch of water.

This stove has a chimney-valve, area of passage 10.5 square feet, in which there must be estimated two right-angle bends, consisting of a rather easy turn of this order, getting out of the stove, a sharp, hard turn, turning down, and another rather easy turn into the flue:

The velocity (temperature 560°) is 24.4 feet per second. Hence, $h = \frac{(24.4^2)}{64.4}\left(3 + \frac{0.0248}{1}\right) = 28$ feet, which multiplied by the weight per cubic foot of the gas passing out, viz.: .0473 pound $= 1.32$ pounds per foot, or 0.25 inch of water.

The inflow-resistance of gas and air at this volume is 0.3 inch of water. At larger volumes this loss is much reduced and may, with very large valves, be lowered to $\frac{1}{8}$ of an inch of water.

The sum of the resistances to the flow of gas in an ordinary Whitwell stove, as now built, is therefore in inches of water:

| | |
|---|---|
| Inflow-resistance of gas and air, or suction in combustion-chamber, with the stove, | 0.30 |
| From bottom of combustion-chamber to bottom of chimney-chamber, | 0.36 |
| Chimney-valve and entrance to chimney-flue, | 0.25 |
| | 0.91 |

About 1 inch of draft is therefore necessary in the chimney-flue for the performance herein considered. Whether the flow is exactly expressed or not, the actual observations are so near these calculations that practical correctness is considered established.

The fact that firebrick-stove power is limited by the heat received by the brickwork, and this in turn is measured by the product of the weight of the gas and the temperature which it parts with, makes it obviously desirable to increase the flow, that the capacity for work may be increased per given expenditure for plant.

We might reduce the inflow-resistance to half, say .15; and the chimney-valve might, in practice, be enlarged to 15 feet area. The possible flow of gas under these conditions and with 1¼ inches of draft in flue, would be 170 cubic feet.*

The resistance in a valve of 15 feet area, with a velocity for 170 cubic feet per second, of 23.8 feet, would be:

$$\frac{23.8^2}{64.4}\left(3 + \frac{0.0248}{1.25}\right) = \frac{27.52 \times .0473}{5.12} = \text{inches of water } .255.$$

| | |
|---|---|
| Lowest possible friction of gas and air entrance, | .15 |
| Plus loss of head inside the stove, | .887 |
| Plus loss of head-valve area, 15 square feet, | .255 |
| | 1.292 |

Requiring rather more than 1¼ inches draft.

The ultimate flow is only referred to here, that the quantity dealt with may be seen to be nearly the practical limit, and the excess over limit is not too much for the exigencies of practical experience. It was the custom of Witherow & Gordon to give for a product of 200 tons a day three such stoves as these, or even the same sizes raised in height, which, as can be readily established from foregoing considerations, is a detriment rather than a benefit. I mean that three 21 × 60-foot stoves can be used to impart more heat to blast than three 21 × 70-foot stoves, as they have been constructed heretofore. The 1824 pounds of blast used in the foregoing calculation is about equal to 200 tons of daily product on good ores.

* Resistance being as the square of the velocity. The loss of head due to flow within the stoves. $2.373 \times 170 \div 116 = 5.12$ — static head $.5 = 4.62 \times .192 =$ inches water .887.

To improve the stove in the line of its capacity to consume a much larger quantity of gas, and pass these products of combustion through itself, is the true line of improvement of a fire-brick stove; and this may be carried as far as the capacity for taking up heat by brick-work will permit, so that two stoves will do the work of three without materially increasing the size.

A judicious limit of size for high heats is reached in the present proportioning of the ordinary Whitwell stove, where there is a fall of some 80° F. during the blow. If one other stove of similar dimensions can be made to take up the gas-heat economically, the limit of economy will be reached by this system, so far at least as quantity of material is concerned.

Splitting the plant of two stoves as above into four, two on gas and two on blast, increases the cost of connections only, and permits much steadier temperature of blast by altering one stove at a time. This plan is advised in plants of moderate or large size.

---

## *GORDON'S IMPROVED WHITWELL-COWPER FIRE-BRICK HOT-BLAST STOVE.*

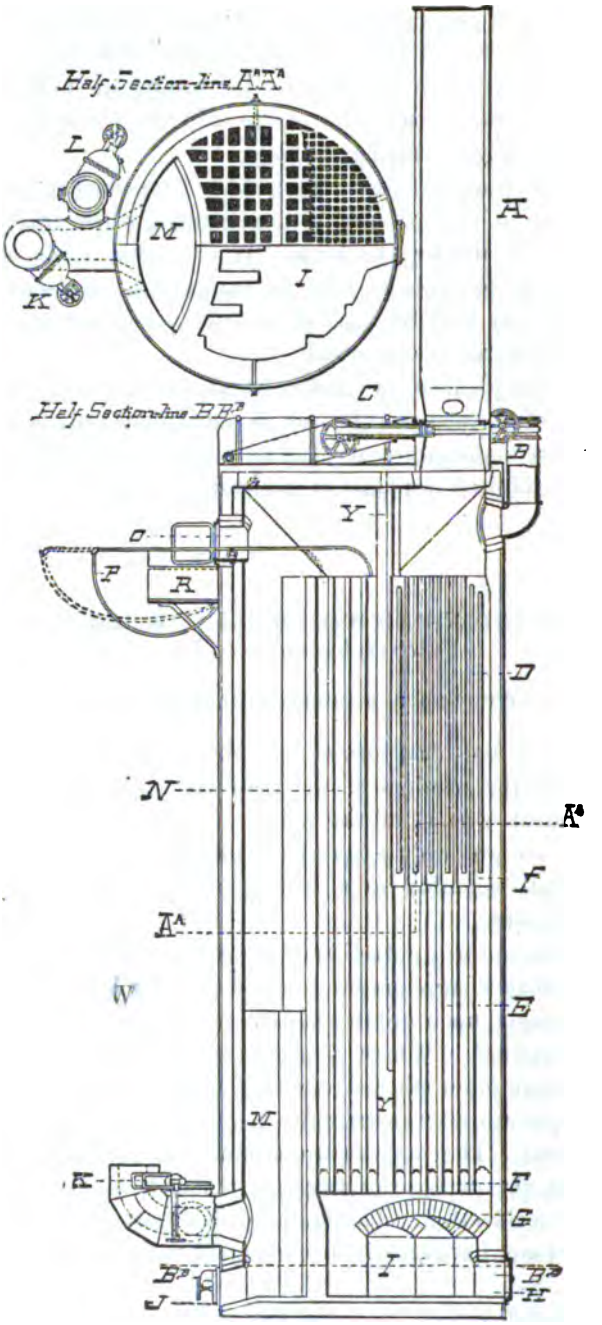
BY VICTOR O. STROBEL, PHILADELPHIA, PA.

FIRE-BRICK hot-blast stoves have been the subject of frequent discussions at the meetings of the Institute; and although it is my object to elucidate some of the points in connection with this subject, I will not go into the specific features of all types, but more especially call attention to a new type recently designed by Mr. Fred. W. Gordon.

As the economical production of a ton of pig-iron is a more essential feature than a large output, much depends, where fuel cannot be obtained cheaply, upon suitable apparatus whereby high temperatures can be maintained. Where iron-pipe stoves have been employed, the fuel-consumption reached one and a half pounds of fuel, and, when a larger output was desired, often two pounds, to the pound of iron produced. The temperature attained rarely exceeded 900° F., and that at the expense of frequent renewals of the pipes, which was not inconsiderable. The fire-brick hot-blast stoves of the past five or six years have clearly demonstrated their superiority over the old system.

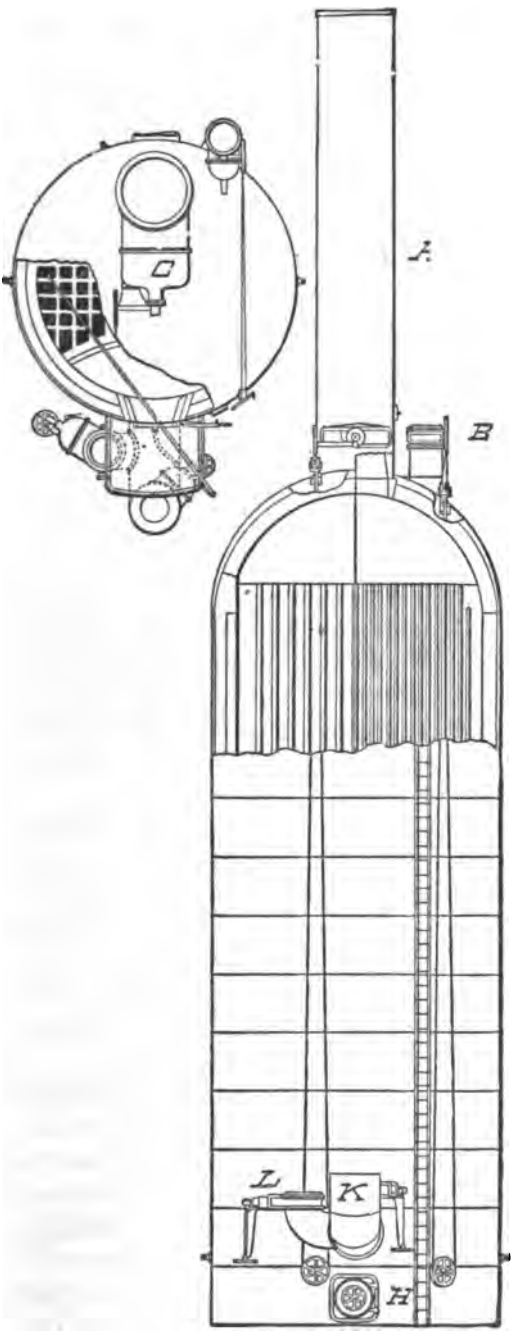
Of the accompanying drawings, Fig. 3 illustrates a four-pass regen-

FIG. 1.




Gordon Three-pass Stove.

FIG. 2.




Gordon Three-pass Stove.

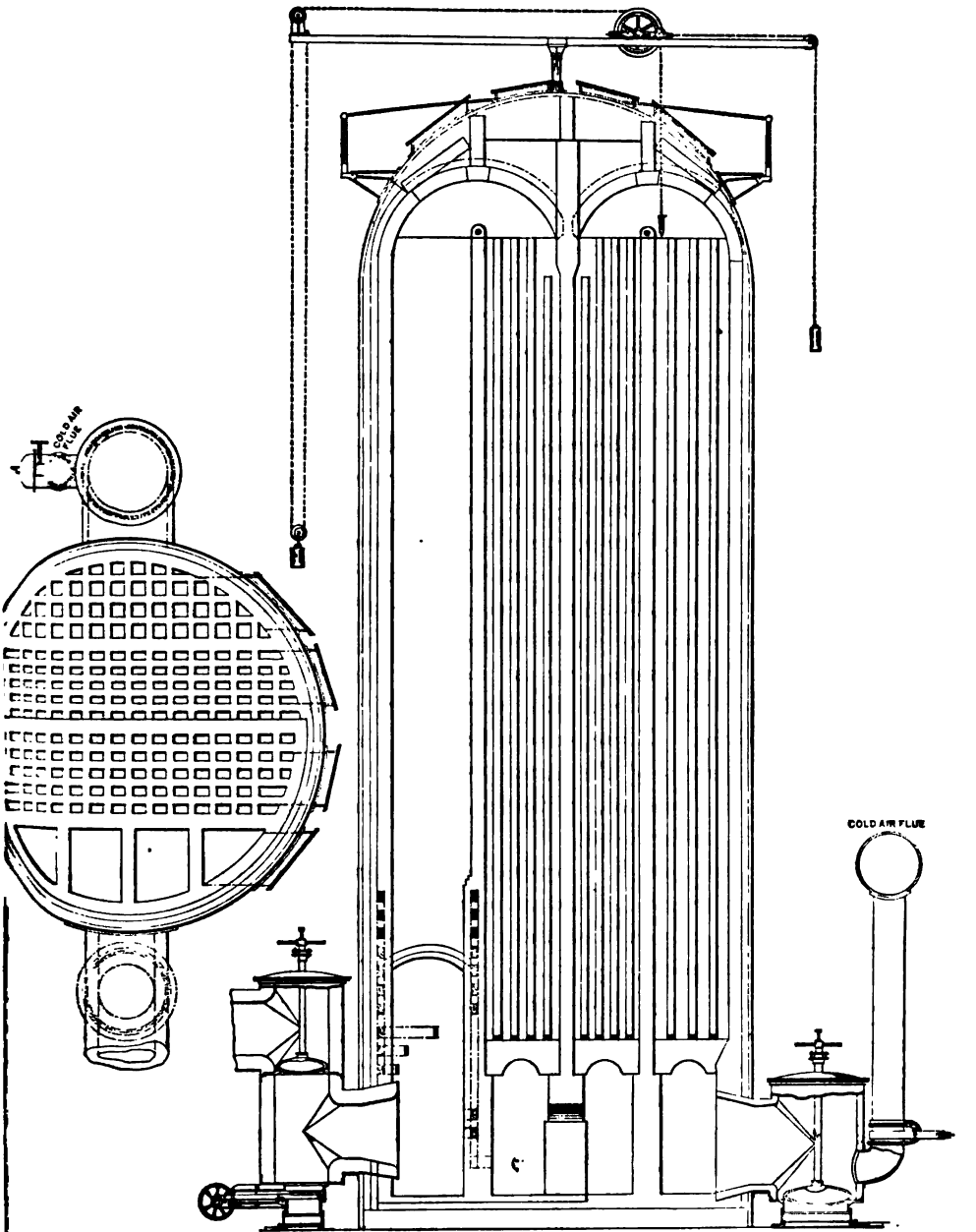
erative hot-blast stove, or what is generally known as the Whitwell hot-blast stove. Figs. 1 and 2 represent a three-pass regenerative hot-blast stove of the improved type to be described. The gas admitted through the valve L into the combustion chamber M, where it is thoroughly oxidized, passing up the chamber M, descending through the regenerative flues N into the chamber I, then ascends through the regenerator flues E and D, and directly to the atmosphere through the draft-stack A. In the four-pass stove, this gas makes another downward turn, passing out of the chimney-valve into an underground flue to the draft-stack at some remote point. In the three-pass stove, the air-blast, taking a reverse direction, is admitted into the chamber X through the valve B, descending through the regenerative flues D and E into the chamber I, then ascending through the regenerative flues N, and descending again, passing out of the stove through the valve K.

As tests have shown the temperature of the burning gas in the chamber N to be five times greater than that of the gas escaping into the chamber X, the division-wall Y is subjected to much greater heats upon the one side than upon the other. In the four-pass stove, Fig. 3, this division-wall is bonded into the regenerative flue-work of both passes. The different qualities of fire-brick in these passes, together with the difference in temperature to which they are subjected, has frequently broken this bond, resulting in the displacement of bricks in the flues, thereby causing a serious impediment to cleaning, and to the flow of gases.

In the three-pass stove, Figs. 1 and 2, this difficulty is avoided by splitting the division-wall Y, thus virtually forming a stove in two longitudinal parts which are free to expand independent of each other. The bottom of this wall is bonded together, and as the linear expansion in this distance of ten or fifteen feet of brick is almost insignificant, owing to the slight difference in temperature, no objection can be made. It also serves to make a seal between the regenerators N and E, when the gas is being transferred. This entire regenerative work is built upon a series of longitudinal arches G. The lintels F, upon which is built the checker-work, are supported upon these arches. By this disposition of arches the entire space under the regenerators is embodied in one. This is a feature worthy of notice; for after scraping and cleaning the walls in the regenerator N, the dust can be removed through a single door H, the sides of which are flared, permitting easy access to any part of the space.

Each of the nine-inch square flues in the last pass E, of the re-

FIG. 3.




Whitwell Stove of 1880.

generator, is divided into four smaller flues, as shown at D, increasing the heating-surface 90 per cent., but decreasing the area only 12½ per cent. The mass of material, however, is increased 22 per cent. The gas, upon reaching this part of the regenerator, has given up much of its heat; but as the absorbing mass has been increased, and the gas subdivided into four parts, and brought into contact with nearly double the heating-surface, a greater proportion of the heat is here taken up from the escaping gases. This reduction of area has a tendency to increase the loss of head due to friction, but the flues in the lower part of the regenerator have been increased in area over the usual amount, thus compensating for the loss.

The stove shown in Figs. 1 and 2 is divided into three passes, increasing the area of each very considerably, and consequently permitting a much greater volume of gas to be passed through them in a given time. The resistance in the flow of gas due to the long, contracted areas of the four-pass system requires enormous underground flues and draft-stacks; and since the gas in the last pass in these stoves rarely, if ever, exceeds the temperature of 500° F., the stove does not develop its maximum power. In the three-pass stove, the gas will pass off at a temperature of 600° F., having previously imparted its heat to an absorbing mass equal to that of the four-pass stove. As I have previously stated, the subdivision of the flues D has increased the heating-surface, giving in the aggregate 25 per cent. more. If the same volume of gas be passed through the increased areas of the three-pass stove, the draft requisite must be materially lessened, or the volume of gas may be increased until a like draft is attained.

For instance, for a product of two hundred tons of iron per day we propose two of the improved stoves, 23 feet in diameter by 60 feet high, one on blast and one on gas. It is required, according to our proposition, to pass 260 cubic feet of gas per second through the one which is being heated, that it may have imparted to it as much heat as the two on gas in a plant of three Whitwells. Or, we would introduce four stoves, two on gas and two on blast, having the same aggregate cross-section internal area as the two 23 by 60 stoves. This would be four 17 by 60-foot stoves. As these four stoves with valves proportional would have exactly the same material in them as the above two, the cost would be almost identical.

For comparison we will take two of the ordinary 20 by 60 Whitwell stoves on gas, the third one being on blast. Then upon the

same theoretical basis as that used by Mr. Gordon, in his paper on the flow of gases, the stove-areas would be as follows:

23 × 60 *Stove.*

| | Area. | Perimeter. | Hydraulic mean depth. | Length. | Absolute Temperature |
|---|---|---|---|---|---|
| | sq. ft. | feet. | feet. | feet. | F |
| Combustion-chamber.. | 48 | 35 | 1.38 | 42 | 2700° |
| First down-pass..... | 55 | 288 | 0.2 | 42 | 2200° |
| Lower part of up-pass | 55 | 288 | 0.2 | 21 | 1700° |
| Upper part of up-pass | 51 | 552 | 0.09 | 21 | 1400° |
| Chimney..... | 18 | 18 | 1.2 | 42 | 1200° |

We calculate by Mr. Gordon's formulas the velocity and loss of head for each as follows:

Combustion-chamber:

$$v = \frac{260 \times 2700}{48 \times 461} = 31.7 \text{ ft.}; \quad h = \frac{31.7^2}{64.4}\left(1 \times \frac{0.02 \times 42}{1.38}\right) = 25.116 \text{ ft.}$$

First down-pass:

$$v = \frac{260 \times 2200}{55 \times 461} = 22.6 \text{ ft.}; \quad h = \frac{22.6^2}{64.4}\left(1 \times \frac{0.02 \times 42}{0.2}\right) = 41.6 \text{ ft.}$$

Lower part of up-pass:

$$v = \frac{260 \times 1700}{55 \times 461} = 17.4 \text{ ft.}; \quad h = \frac{17.4^2}{64.4}\left(1 \times \frac{0.02 \times 21}{0.2}\right) = 12.57 \text{ ft.}$$

Upper part of up-pass:

$$v = \frac{260 \times 1400}{51 \times 461} = 37.6 \text{ ft.}; \quad h = \frac{15.5^2}{64.4}\left(1 \times \frac{0.02 \times 21}{0.09}\right) = 17.39 \text{ ft.}$$

Chimney:

$$v = \frac{260 \times 1200}{18 \times 461} = 37.6 \text{ ft.}; \quad h = \frac{37.6^2}{64.4}\left(1 \times \frac{0.02 \times 42}{1.2}\right) = 24.2 \text{ ft.}$$

This head in columns of hot gases multiplied by the weight per cubic foot of gas at the respective temperatures gives the loss of head in pounds per square foot.

| | | | | | | |
|---|---|---|---|---|---|---|
| Combustion-chamber..... | 2700° | = | 0.0176 | × | 25 1 | = .442 |
| First down-pass..... | 2200° | = | 0.0215 | × | 41.6 | = .894 |
| Lower up-pass..... | 1700° | = | 0.0284 | × | 12.6 | = .358 |
| Upper up-pass..... | 1400° | = | 0.0337 | × | 17.4 | = .586 |
| Chimney..... | 1200° | = | 0.04 | × | 24.2 | = .968 |
| Total loss of head in pounds per square foot..... | | | | | | 3 348 |

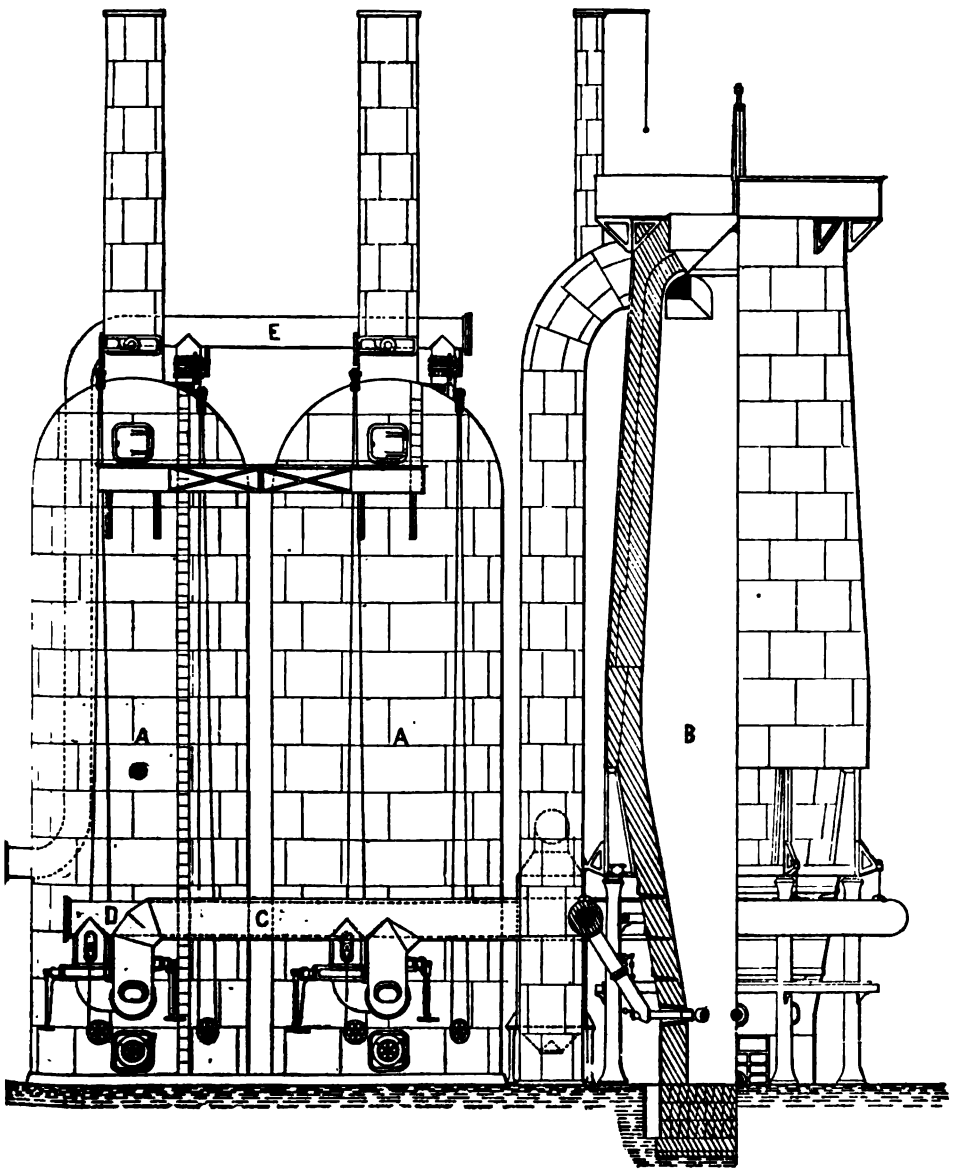
The static head due to difference between the specific weight of the gases and that of air is:

| | | | | |
|---|---|---|---|---|
| Combustion-chamber | 42 (0.076 | — .0176 | = | 2.457 |
| Up-pass | 42 (0.076 | — .031 | = | 1.89 |
| Chimney | 50 (0.076 | — .04 | = | 1.8 |
| Total | | | | 6.147 |
| Down pass. The negative head | 42 (0 076 | — .0215 | = | 2.28 |
| Add loss of head due flow of gases | | | = | 3.348 |
| And that due to gas- and air-induction | | | = | .51 |
| Total negative and loss | | | | 6.1383 |

which is nearly equal to the static head. This 23 by 60-foot stove will take double the volume of gas that can be passed through one 20 by 60-foot Whitwell stove. Hence one of these 23 by 60-foot stoves will perform what two 20 by 60-foot Whitwells have heretofore done.

When very high temperature of blast is required, an arrangement for the uniform heating of the whole regenerator is effected by passing a portion of the products of combustion into the chamber I, Fig. 1, under the regenerator carrying their maximum sensible heat. The temperature of the last pass of the regenerator can therefore be made equal to that of the first pass, the escaping gases passing off at a temperature of 1400° to 2000°, again illustrating how the entire mass of brick-work, equal to that in the Whitwell stove, is subjected to higher heats. This flow of gas from the combustion-chamber is introduced through a port, in which a fire-brick plug will regulate the quantity of gas desired. The strong draft through the last pass of the regenerator draws the products rapidly through, and takes from the current which usually passes up the combustion-chamber a large portion of the dust, which is deposited in the chamber I, and can readily be removed through the cleaning-door H. It will be observed that this gas is taken from a point in the combustion-chamber where a thorough mixture of the air and gas is to be had. Owing to the greatly increased volume and velocity of the gas passing through this stove, the tendency for accumulation of dirt will be materially reduced, the strong draft carrying most of the dirty gases with it. For cleaning the stoves a very simple device is used, consisting of an ordinary piece of gas-pipe, P, introduced through a single opening, O, at the top of the stove, and so located that each and every flue-hole in the first down-pass may be reached. In case the upper part of the regenerator becomes encrusted with dirt, a scraping-plate and plummet with the proper sheaves is substituted. The last two passes of regenerators very rarely if ever

FIG. 4.




Plant of Three-Pass Stoves. Elevation.

require cleaning, as the whole deposit seems to be concentrated in parts where the gases are highly rarefied; which, in any stove, is invariably the first down-pass. This difficulty has been experienced by those who have used the Cowper stove.

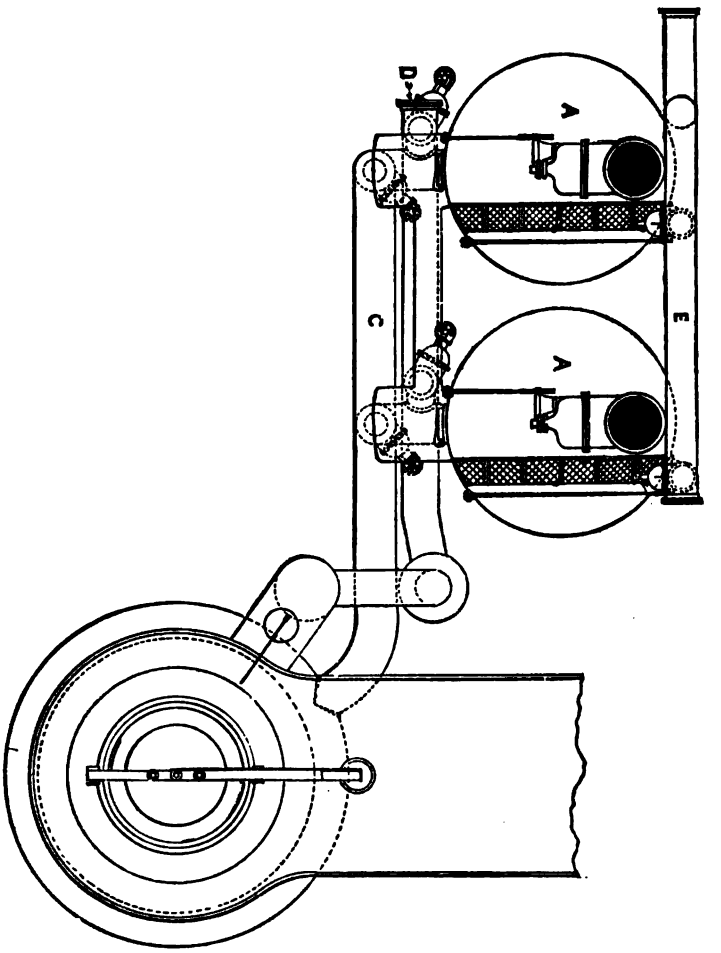
Yet it is clearly demonstrated by practice that very little cleaning is necessary when the gases are passed through a dust-catcher. By the cleaning-device, as shown in the four-pass stove, great difficulty is experienced in removing the material in the numerous holes, through each of which only a few flues can be cleaned. This difficulty often proved to be the cause of poorly-working stoves. Much time was lost in removing these lids and the brick filling, and consequently the cleaning operation was postponed, until in many cases the heating power of the stove was reduced to one-half its actual capacity. The device shown in the three-pass stove simplifies this operation; the whole time occupied in performing what formerly took from six to eight hours being about one hour.

Figs. 4 and 5 exhibit a general plan of a furnace with a plant of three-pass stoves. A A are the stoves, B is the furnace, C the overhead gas-main to dust-catcher, D the dust-catcher, which is used exclusively for the gas to be burned in the stoves. This we consider a highly important appurtenance to the stoves, and think it should, in all cases, be adopted.

I here wish to explain some of the details of valve-construction in connection with hot-blast stoves. The hot-blast valve and gas-valve, in Fig. 3, are frequently burned by premature combustion of the gases in the space between them, and must be replaced. When the stove is on gas, this space, of course, forms the conduit to the combustion-chamber, but the leakage of air-blast through the valve immediately ignites the gas and both are subjected to this intense flame. In the stove exhibited in Figs. 1 and 2, the disposition of these valves is such that the products cannot come in contact with each other short of the stove combustion-chamber. The hot-blast valve in this case, details of which are seen in Figs. 6, 7 and 8, is of the gate-type, and pierces the wrought-iron elbow in its vertical portion. The valve L, similar in construction to K, is bolted upon a cast-iron elbow and engages the wrought-iron elbow in its horizontal portion on one side, close up to its connection with the stove-shell. Any leakage in the valve K will therefore meet this gas at the point where it enters the conduit in the wrought-iron elbow, close up to the orifice to the combustion-chamber, thereby securing the safety of both valves. The varying temperatures to which these valves are

subjected make it a matter of extreme difficulty to avoid their warping and the destruction of the valve-seats. The puppet-form hot-blast valve shown in Fig. 3 has given more or less trouble in this direction, and when a replacement of the seat was necessary the

FIG. 5.




Plant of Three-Pass Stoves. Plan.

entire mass of brick-work above the seat had to be removed, entailing a great loss of time and work. The sliding hot-blast valve renders this operation, when necessary, quite simple. The valve shown in Fig. 5 presents several novel features. The seat A, Fig. 1, is a hollow phosphor-bronze casting, fitted into a ring C, with a

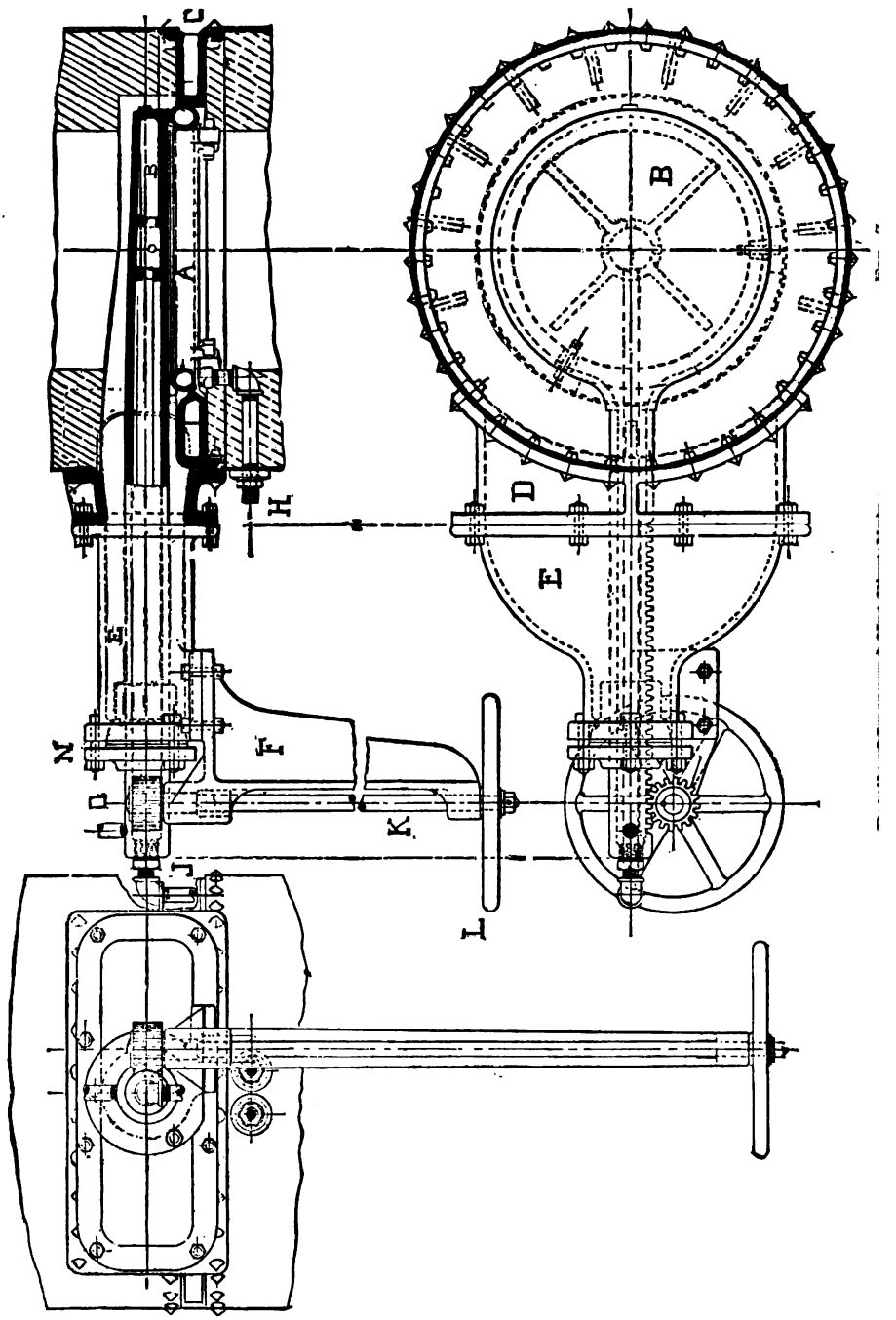



FIG. 6.

FIG. 8.

slightly tapered or spherical joint. The body of the valve consists of a simple neck, riveted to the wrought-iron elbow and engaging the ring C on the bottom flange. The cap E is bolted to this neck. The gland N is fitted to this cap with a spherical joint. If, therefore, the valve-seat A should get out of line, adjustment can be effected with the keys, the spherical joint before mentioned permitting sufficient movement, and retaining a tight joint. This adjustment is compensated at the other end of the valve by the ball-jointed gland N. To replace a valve-seat merely necessitates the removal of the cap E and a man-hole cap underneath this, through which the new seat may be adjusted. All the air for combustion is admitted through a single opening directly under the gas-inlet to the stove, insuring a thorough mixture of the products. This air-valve which is of the puppet form is attached to a hinged door, and also forms an opening in the bottom of the combustion-chamber for the removal of dirt. The entire bottom of this chamber can be reached through this single door with great ease. The chimney-valve, placed in the bottom of the chimney on top of the stove as shown in Fig. 3, is constructed in a similar manner, the hollow space in the valve-seat being made doubly large to permit a strong current of air to pass through it for cooling. This current is established by the stove chimney. The same draft also serves to cool the large circular disk-valve.

The chimneys of these stoves are strongly built, commencing with heavy plate on the bottom and thinning at the top. They are lined with 4½ inches of fire-brick. The cold-blast valve B is an ordinary slide-gate valve operated with a rack and pinion. On the main valve an auxiliary or small valve is placed for the purpose of equalizing the pressure on both sides of the valve, lessening the power which would be required to move the large valve with the full pressure on. The chimney and cold-blast valves are operated from a common station at the bottom of the stove with ordinary wire ropes passing over grip-sheaves. The operation of changing a stove from gas to blast or *vice versa* is so simple that an ordinary laborer can attend to the operation of the stoves. The operating wheels are arranged in the order necessary to make the change. Beginning at the right, the cold-blast valve is closed. The next in regular order is the hot-blast valve. Then the air valve, chimney-valve and gas-valve are each opened in their respective order. This operation changing the stove from blast to gas, the reverse of it will change the stove from gas to blast.

In conclusion I give here a comparative exhibit of the cost of plants of these stoves, the Player 18-pipe hot-blast stove and the Whitwell fire-brick stoves, capable of making a weekly product of 500 tons:

| | |
|---|---|
| A plant of five 18-pipe Player hot-blast stoves would cost, . | $22,000 |
| A plant of two Whitwells, . . . . . | 26,000 |
| A plant of two Gordon's Improved, . . . . . | 19,000 |

The foundation in all cases being omitted. This item for the Player stoves would almost run their cost up to that of the Whitwell plant. The advantages claimed for this stove are therefore:

1. Its simplicity of construction, avoiding the costly underground chimney-flues and draft-stack.

2. The increased area of passes and valves, permitting 50 per cent. more gas to be passed through them.

3. The capacity of heating a greater volume of blast to a higher temperature.

4. Finally, its low initial cost as compared with other fire-brick stoves.

---

## *THE GEOLOGY AND MINERAL RESOURCES OF SEQUACHEE VALLEY, TENNESSEE.*

BY W. M. BOWRON, SOUTH PITTSBURGH, TENN.

SEQUACHEE Valley includes portions of the counties of Marion, Sequachee, Bledsoe and Cumberland. It extends in a general direction parallel with the Great Valley of East Tennessee, some 75 miles northward from the Alabama state line. It is separated from the Valley of East Tennessee by a mountain arm about a dozen miles wide, known as Wallen's or Walden's Ridge.

The genesis of the valley, geologically speaking, is simple. It is an erosion-valley along the axis of an anticlinal. The point of the wedge remains in a row of low "saw-tooth" hills, running up the center of the valley. These hills are of Lower Silurian age, and consist of Trenton limestone, covered and protected in some measure by chert. Walls of Carboniferous age form the inclosing mountains on either side; whilst a magnificent arch of Hudson River, Niagara, Hamilton and Subcarboniferous strata closes the valley at the

northern end, and under its colossal folds flows in subterranean course the Sequachee River. This river rises in Grassy Cove (a depression in the line of the Sequachee valley, 4 miles long by 1½ miles wide,—technically, a huge sink-hole) and flows 8 miles underground. This feature has been eliminated from the accompanying map in the process of engraving; and the river consequently appears to be wholly disconnected with Grassy Cove. Its course from its head can be laid down on the map as follows: From the upper left hand (west) corner of the cove, curving south and east around and below the words "Grassy Cove," then north and west, roughly parallel with the outer edge of the cove, to a point just to the right (northeast) of the promontory in the middle of the upper (northwest) side. At this point it disappears, to reappear at the head of the main valley. Its subterranean course is probably northwest, west, and south, in a curve just clearing the cove, and passing not far from the original head.

The succession of rocks on the east side of the valley is normal, and agrees with our usual Tennessee sequence. The strata on the west side of the valley have been thrown down by a fault several hundred feet, bringing rocks of probably Keokuk age in contact with the Trenton of the Middle Ridge. In saying that the rocks were "thrown down," I use the phrase in its accepted conventional meaning. Prof. J. P. Lesley is quoted in Macfarlane's *Coal Regions of America* * as follows:

"The juxtaposition of the upper Silurian ore of V. in East Tennessee with the beds of the coal-measures XII. is a striking phenomenon, but one not peculiar to that region. We have before spoken of the great down-throw faults which run in straight lines from Alabama to Middle Virginia. It is to these faults that we owe the existence of the Cumberland Mountain range and the preservation of the coal-beds. Before these faults took place, the coal was elevated on a plateau, covered with eternal snow and ice, from 10,000 to 20,000 feet above the level of the sea. When this plateau was cracked along parallel lines running east-northeast and west-southwest, intermediate sections of it dropped to about 3000 feet above tide-level. The sections that retained their elevation have been eroded of all their coal measures as far down as the fossil ore."

One might be tempted to inquire by what means the *bottom* of the cañons so formed, and composed of coal-measures, escaped denudation, when the snow and ice melted on the portions which "retained

* 1st edition, page 364.

their elevation." In fact, there are many other questions that would rise to the surface, were the hypothesis above quoted tenable.

A careful study of our East Tennessee faults and the plications of the strata will prove the following:

1. That at no time was the Cumberland mountain much above its present level.

2. That the Appalachian system was raised by a crushing or crumbling together of the strata, and that to this we owe all of our peculiar East Tennessee geology.

3. That the movement was a very slow one—"a few inches a century accords best with the facts," as Professor Dana says of the changes of level in Carboniferous ages.

4. That the action was practically this: With the slow corrugation of the oldest strata, consequent on Appalachian squeezing together, the superincumbent strata were uplifted, and, in most cases near the disturbing force, fissured on the line of the anticlinals; and the *side nearest the disturbing force*, in most, if not in all, cases, *outtravelled the other* in being squeezed upward. The whole surface of the country being at or near water level at the time, denudation removed the material supplied at a rate at least equal to its progress upward, thus eroding the valley of East Tennessee.

5. That the action commenced at the close of Carboniferous time and was continued certainly for a very long period—possibly down to the present day.

As to the former height of Cumberland Mountain, and the evidences for or against the alleged "down-throw," we find that at the head of Sequachee valley the fault becomes gradually smaller and is effaced as it goes into the mountain. The wedge of Trenton rocks still underlies the mountain, but the strata up to the Carboniferous are flexed over it and not fissured; and the Hog-back mountain of Crab Orchard is the result. Coming southward from Crab Orchard, the axis of the fold has been fissured, the crack has been eroded, and the east side has been raised faster than the west side, thus forming the Sequachee Valley fault described above.

It would be easy to imagine and describe ocean-flows, Triassic gulf-streams, and land-drainages to account for the contours of the district under consideration; but such hypotheses are not susceptible of proof. Probability would lie in the direction of changes of current as the ground assumed different levels. That the movement was a very slow one, no one who has examined the rock-conditions of the Alleghanies will doubt. In the formations of this system,

rocks occur from Niagara to Carboniferous in several districts, with limestones present in large quantities. A more brittle rock than limestone is rarely shown in mountain masses. It has little or no flexibility. If broken in place it heals; but a cicatrix of calcite attests the former injury. Some years ago a paper was read before this Institute on the flow of metals under pressure. The principle was admitted, and experiment showed that, in addition to pressure, time for molecular rearrangement was an essential factor. This applies to the Appalachian limestones. Those who have seen the wonderful plications of these strata must admit that time as well as pressure was an element in their formation.

In the Sequachee valley we have a further proof of the slowness of these upheavals, and a convincing proof of the fact that for some time past the Sequachee valley has had the same general outline as it has now. This has been the case since the time when the floor of the valley was Devonian black shale. The little creeks, flowing from the sides of the confining mountains in the same gorges as they now occupy, removed the black shale from their channels. In after ages, when the floor of the valley had been deepened so as to drain the Clinton beds, infiltration of iron from the black shale converted the limestone into ore, except in the beds of the creeks, where the limestone is but partially altered. An example of this may be studied at Ketner's Cove, a few miles above Inman. The ore is only a foot or so thick, with three feet of limestone, beside the mill at the bottom of the hollow, while on the hill, away from this influence, the four feet is all ore. The Sequachee river runs on the axis of the upturned Trenton limestone. Softer rocks are on both sides of it, but through numberless ages the water dissolved out its bed before any other channel was possible.

Leaving abstract geology for the present and returning to the subject of the iron-ore, we find it out-cropping in place for many miles.

The analyses of these ores are as follows:

| | $Fe_2O_3$ | $SiO_2$ | $P_2O_5$ | $Al_2O_3$ | $CaCO_3$ |
|---|---|---|---|---|---|
| *Inman soft ore | 66.47 | 18.60 | 2.49 | 10.29 | ... |
| do. hard ore | 55.40 | 17.36 | .71 | 5.77 | 15.55 |
| do. (hard from tunnel) | 45.80 | 10.04 | .82 | 3.72 | 37.42 |
| do. (hard ore stripped) | 43.83 | 10.54 | 1.17 | 7.86 | 35.24 |

* Outcrop samples.

The lack of analyses from other localities is explained by the fact that no developments have been made above Inman. The land is in the hands of the farmers, and has escaped so far the grasp of the speculators, because owing to want of railroad facilities these ores were inaccessible.

As the early completion of a railroad into the valley is confidently expected, these ores will probably be brought into use.

In mining the ore presents no special difficulty. It lies in a sheet upturned towards the center of the valley and going with a gradually lessening dip into the mountain as shown by the section on the accompanying plate. This sheet protected the strata below from weathering and so formed a "bench." Drainage has cut through it and the result is a row of foot-hills sheeted on the back with ore. This is stripped and worked in the usual manner. Upon going into the mountain, although working to the dip, no water has yet appeared, the ground being drained by lower strata.

At an average distance of four miles from the ore lies the coal, a clean, pure, semi-bituminous fuel, with an average thickness of four feet. The quantity of coal available for mining from the Sequachee valley is enormous. Not all the coal in the mountain, however, can be reached from this point, for the mountains slope away from Sequachee valley on both sides and the strata dip into the mountain.

Upon the Cumberland plateau of Lower Carboniferous age is superimposed a second mountain of the upper coal-measures.

When the slow uprise (which originated Sequachee Valley) had altered the drainage of Cumberland mountain, the upper mountain dammed the waters from flowing to the westward. The waters accumulated and formed lakes, which (as the uprise was so slow) overflowed the slight elevation behind them and fell back into the valley. For ages after the main valley was practically excavated, this drainage continued and cut out the cañon-like gorges of Little Sequachee, Griffiths Creek and Brush Creek. The gradual uprise continuing, the lowest portions of the upper mountain were overcome by the waters, and the drainage went again to the westward. The perpendicular sides of these former river beds are very suggestive of some of the smaller cañoned streams in Colorado. Opposite the mouth of each stream of this character, the middle ridge of the valley is obliterated. This gives convenient crossing-places for getting the coal and iron together, besides providing suitable furnace-sites.

The Sequachee uplift has had a marked effect on the coal. At a

certain distance from the middle of Sequachee valley, and roughly parallel with it, the strata are somewhat sharply bent to accord with the new dip caused by the anticlinal of the valley. This has conferred on some of the coal a peculiar spumous or pseudo-lenticular structure, which does not interfere with its purity or with its coking-value, but makes it difficult to carry in the shape of "lump" without shaking down to "small" in transit.

East and west of this belt of disturbed coal is an ordinary cubic-bedded, clean fuel; but the bend that crushed the coal bulged it in some places, and squeezed it in others. I have known it pinched down to 6 inches, and, on the other hand, I can show it in a thickness of 17 feet. Influences of the same class at Rockwood have made the coal 100 feet thick in places.

I may call this belt the axis of disturbance. This axis of disturbance runs a few miles back from the valley in places and approaches it in others. I have approximately placed it on the accompanying map.

The practical result of these conditions is, that the beds of Little Sequachee and Griffiths Creek in Marion County, and Brush Creek in Sequachee County, render accessible to the locomotive points that tap the coal measures at the lowest point of their dip, and render the mines self-draining.

The following table contains analyses of the coal, with others for comparison:

| | Distance north of Tenn. river. | Carbon. | Ash. | Volatile matter. | S. |
|---|---|---|---|---|---|
| *Tracy City | 18 | 63.5 | 6.6 | 29.9 | (?) |
| †Whitwell | 15 | 60 50 | 8.10 | 31.40 | 0.371 |
| Hedley & Hoge | 50 | 74.06 | 7.19 | 18.75 | 0.484 |
| ‡Connelsville | ... | 59.62 | 8.23 | 31.36 | 0.784 |
| ⁋Peases West. English | ... | 83.27 | 1.52 | 8.21 | (?) |

The ash of the Tracy coal I examined with the following result:

---

* Analysis published by company mining the coal.

† Analysis by Britton.

‡ Analysis by A. S McCreath.

⁋ Analysis by Dr. Richardson, of Newcastle-on-Tyne.

| | |
|---|---|
| Silica, | 50.65 |
| Alumina, | 44.83 |
| Ferric oxide, | 2.72 |
| Lime, | .32 |
| Magnesia, | 0.11 |
| Sulphur, | .53 |
| Phosphoric acid, | 0.072 |
| Titanic acid, traces | |
| Alkalies, loss and ingredients not estimated, | 0.768 |
| | 100.000 |

For comparison, the ash from Connellsville coal is given:

| | |
|---|---|
| $SiO_2$, | 47.90 |
| $Al_2O_3$, | 47.76 |
| $Fe_2O_3$, | 1.43 |
| CaO, | 1.48 |
| MgO, | .53 |
| S, traces | |
| $P_2O_5$, | .21 |
| $K_2O$ and $Na_2O$, | .49 |
| Loss, | .20 |
| | 100 00 |

(Britton, analyst.)

The whole of the coal on the Cumberland Mountain is comprised for practical purposes in one seam, the Sewanee seam, from which the samples above named were taken. The ground continuously underlaid with this coal, and tributary by drainage to Sequachee Valley, is about 350 square miles. The coal will average 4 feet, as far as my observation has gone. The following is the section of Cumberland Mountain, according to Professor Safford:

| | Feet. |
|---|---|
| (13) CONGLOMERATE: caprock of the upper plateau and the uppermost stratum in this region, | 50 |
| (12) COAL, a few inches | |
| (11) Shale, | 23 |
| (10) COAL outcrop, | ½ |
| (9) Dark clay shale, | 1 |
| (8) Sandy shale, | 25 |
| (7) Sandstone, | 86 |
| (6) Shale more or less sandy, | 45 |
| (5) COAL, Main Sewanee, | 3–7 |
| (4) Shale, some of it sandy, | 33 |
| (3) COAL outcrop, | 1 |
| (2) Shale, | 3 |
| (1) Sandstone, | 17 |

(Base of Upper Measures).

| | |
|---|---|
| Conglomerate, | 70 |
| Lower Measures: | |
| (10) Coal outcrop, | ½–1 |
| (9) Shale with clay on top, | 10 |
| (8) Cliff-rock sandstone, | 65 |
| (7) Coal outcrop, | ½–1½ |
| (6) Shale, with a few inches clay, | 8 |
| (5) Sandy shale, | 22 |
| (4) Hard sandstone, | 78 |
| (3) Coal with occasionally shale above and below it, | 1–3 |
| (2) Hard sandstone (local), | 70 |
| (1) Shale, | 20 |

(Bottom of Coal Measures).

Mountain limestone, etc.

Of the coke made from the coal in the Sewanee seam, a good test has been made by consecutive work for over 20 years at Tracy City, and a couple of years' mining at Victoria, with coking of the produced coal. The coke is made in "beehive" ovens, usually 11 feet diameter. There is nothing special to note in the coking process, except that owing to the difficulty of procuring skilled labor in isolated districts, the coke is often measurably spoiled by bad management of the ovens.

For years the coke from the Sewanee seam has been one of the standard furnace-fuels of the South. The coal will make either good or bad coke, according to the cleanliness with which it is mined, and the subsequent influence that good or bad coking will exert.

At the furnace at South Pittsburgh, Tracy city coke is used with Inman ore and soft ore from the Birmingham, Alabama, district (here called "Morris" ore). The ores have the following composition, by latest analyses:

| | Fe | $SiO_2$ | $Al_2O_3$ | $CaCO_3$ |
|---|---|---|---|---|
| Morris ore, April 24th | 49.00 | 18.13 | 4.44 | ... |
| " " " 28th | 46 75 | 22.98 | 5.37 | ... |
| " " May 9th | 50.00 | 19.82 | not det. | ... |
| Inman " April 24th | 30.68 | 11.75 | 6.33 | 35.24 |
| " " " 28th | 30 22 | 10.54 | 7.86 | not det. |

The charge was as follows:

| | |
|---|---|
| Coke, | 4000 lbs. |
| Morris ore, | 3500 " |
| Inman ore, | 4200 " |
| Limestone, | none |

The furnace is 70 feet high and has a diameter of 17 feet. The coke used had by last analysis 85.39 carbon and 12.93 ash. The blast used was 7.1 tons to each ton of iron, with an engine-house pressure of 4½ pounds, and a temperature of 1050° F. The make of the furnace was 80 tons of mostly No. 1 foundry iron, with the bottom beds a little closer. At the time the above data were obtained this paper was not foreseen; and no special pains were taken to sample the cinder and gas. As the same burthen, however, was still on the furnace, samples on the 13th May will be near enough to be representative.

The gas gave on examination by weight:

| | |
|---|---|
| Carbonic oxide, | 34.01 |
| Carbonic acid, | 8.07 |
| Nitrogen (by difference), | 57.92 |

Probably the high percentage of CO arises from a reversion from $CO_2$ caused by the larger or smaller quantity of soft coke that seems omnipresent in all furnace coke. The sample was taken by connecting a large glass tube with the down-comer in such a way as to allow the gas to blow freely through it. A minute before the tube was closed the stove-dampers were pushed in a little so as to force the gas through the tube with a good pressure, thus entirely displacing the air. The sample was taken at a time about half-way between charges.

The cinder had the following partial analysis:

| | |
|---|---|
| Silica, | 40.98 |
| Alumina, | 8.77 |
| Lime, | 43.31 |

and the resulting pig-iron (samples taken by boring completely through pig) showed on analysis the composition:

| | |
|---|---|
| Carbon, graphitic, | 3.961 |
| Carbon, combined, | 0.203 |
| Manganese, | 0.027 |
| Sulphur, | 0.041 |
| Phosphorus, | 0.874 |
| Silicon, | 2.520 |
| Iron by difference, | 92.374 |
| | 100.000 |

To diminish the quantity of silicon, attempts have been made to make the charge resemble more nearly the charges quoted by the

SEWARD
CONVENTIONAL SIGNS
SCALE OF MAP 8 MILES TO INCH.

English authorities. The furnace under these conditions responded by a smaller output and a tendency to jump from No. 1 mill-iron to bright iron. An excessive proportion of alumina in the cinder from these ores leads invariably to a dry, pasty cinder, combined with the usual furnace-irregularities, such as "hanging on," "slipping," and "working in a flue."

To the courtesy of the authorities of the Tennessee Coal, Iron & R.R. Co. I am indebted for the above data of charge and heat and for permission to use the analyses made on their account.

A review of the geology of this district would be incomplete were I to omit the palæozoic fault that now lets the Tennessee River through the Cumberland plateau. This fault has not been active, so to speak, since the close of the Carboniferous epoch. On either side the river the alternation of rocks is distinct. Even the number of coal-beds is not the same, pointing to several alternations of level during the deposition of the coal. As one or the other side sank, the edge of the cliff so left was eroded, and by this action a hollow was formed. This hollow, on the subsequent elevation of the land, became a drainage-channel, and is another proof of the immensity of time occupied in the making of our mountains. The upheaval has never been more rapid than the action of the stream, or the Tennessee River would have followed the general course of the great valley and gone to the Gulf of Mexico by way of Montgomery, Ala.

---

## *THE SULPHIDE-DEPOSIT OF SOUTH IRON HILL, LEADVILLE, COLORADO.*

BY FRANCIS T. FREELAND, B.S., DENVER, COL.

THE deeper workings of the Leadville mines show refractory ores, consisting principally of sulphides of iron, lead, and zinc, carrying silver, in place of the easily reduced carbonate ores lying nearer the surface. The largest and most extensively developed deposit is that of South Iron Hill.* It lies on the north side of California Gulch,

* In the fall of 1884 the writer, mining engineer and surveyor to the Iron Silver Mining Company, was directed, with the consent of the managers of the Minnie and Col. Sellers mines, to make an examination of their workings, in connection with the Moyer workings belonging to the Iron Silver Mining Company, for the information of the managers of these adjacent properties. Considerable use has been made of the data collected at that time for those parts of the accompanying

parallel with the gulch, and stretches from the Stone mine to the Moyer shaft in Nugget gulch and beyond. It is the continuation of the carbonate-deposit extending through the Dome, Rock, and Stone mines.

The main ore-chute is from 200 to 300 feet wide, and in places over 60 feet thick. It has been opened for a distance of 1200 feet, with every appearance of continuing into unprospected ground without diminution of strength.

Plate I. is a topographical map of the south end of Iron Hill, showing a portion of the underground workings of the mines within the limits of the map. The map also shows the outcrop of the vein, and the line of demarcation between the carbonate and sulphide-ore. The ore found between the lines marked *Outcrop of Vein* and *Western Limit of Sulphide Ore* is, in general, carbonate-ore, and that found east of the latter, sulphide. In the carbonate-zone there is a mass of sulphide ore, in the deeper workings in the northeast corner of the Stone, where carbonate-ore overlies it. Some carbonate-ore can be found in the sulphide-zone, generally in the form of a thin streak above the sulphide-ore, and, more rarely, as a patch under or in it surrounding a water-course.

There is also shown on the map the line of a fault, not on the surface but at the level of the workings in ore. The Moyer shaft passes through it at the second level, and I have named it the Moyer fault.

Figs. 1 to 3, Plate II. and Figs 4 to 9, represent sections made on certain lines laid down on Plate I. The scale of all these figures is shown on Plate II., when the signs employed for geological distinction are also explained.

The general geology of the hill is clearly shown in the main longitudinal section A D, Fig. 1, Plate II., along line A B C D in Plate I. A partial columnar section, not much east of the outcrop, gives from the surface down: 1st, a variable thickness of white porphyry; 2d, 0 to 160 feet of gray porphyry; 3d, the main contact vein of Iron Hill; 4th, 250 to 300 feet of blue Carboniferous limestone;

plates which cover the above claims. For permission to print facts thus obtained, for tracings of mine-maps, and information in regard to inaccessible workings, thanks are due to William H. Stevens, Chairman Executive Committee, and F. G. White, General Superintendent, Iron Silver Mining Company; W. F. Patrick, Manager Col. Sellers group; Thomas Weir, Manager Minnie and A. Y.; Frank W. Owers, Helen shaft; and W. A. Christian, Gilt Edge No. 2 shaft.

The workings here described have been made for the most part since Mr. S. F. Emmons concluded his admirable study of the Leadville district.

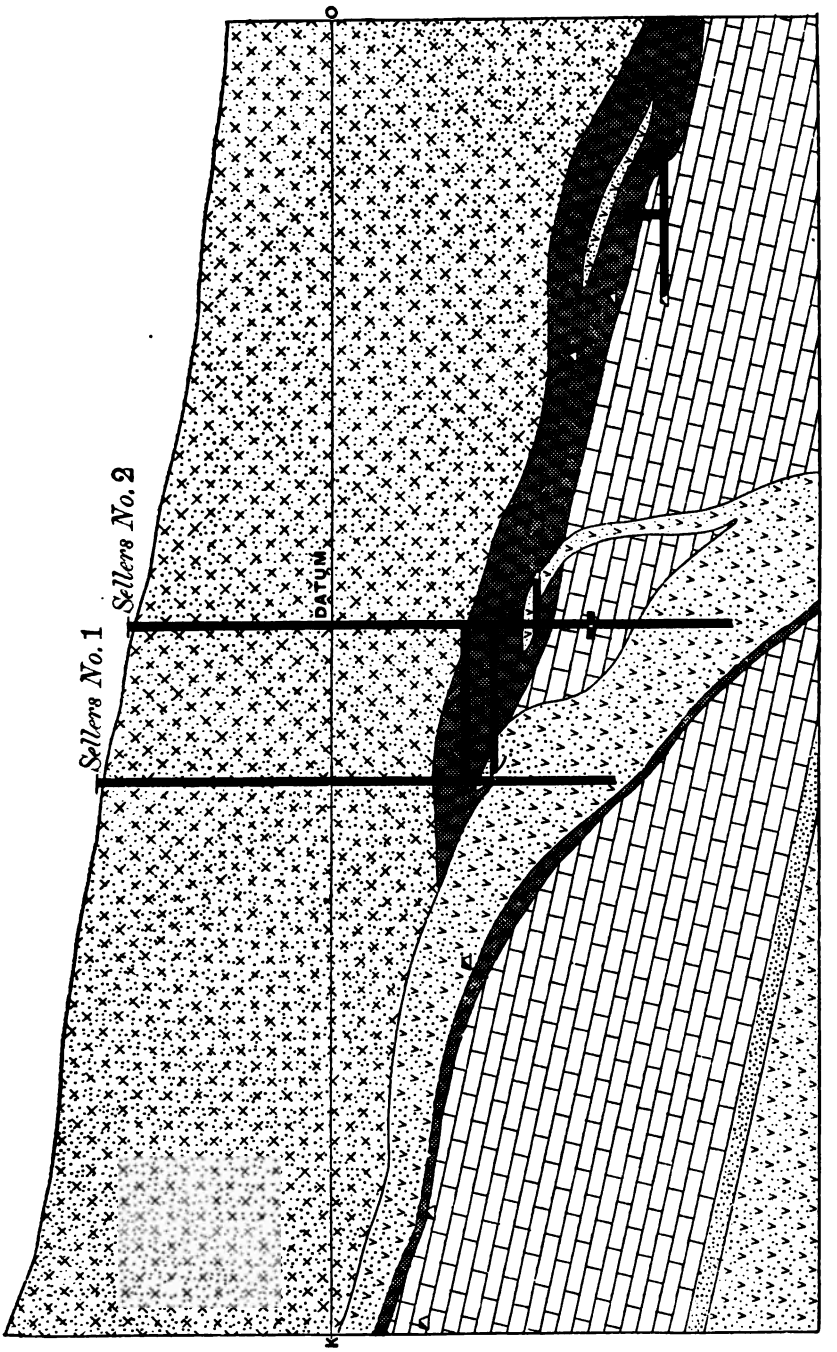



FIG. 4.

Section on line K O, Plate I.

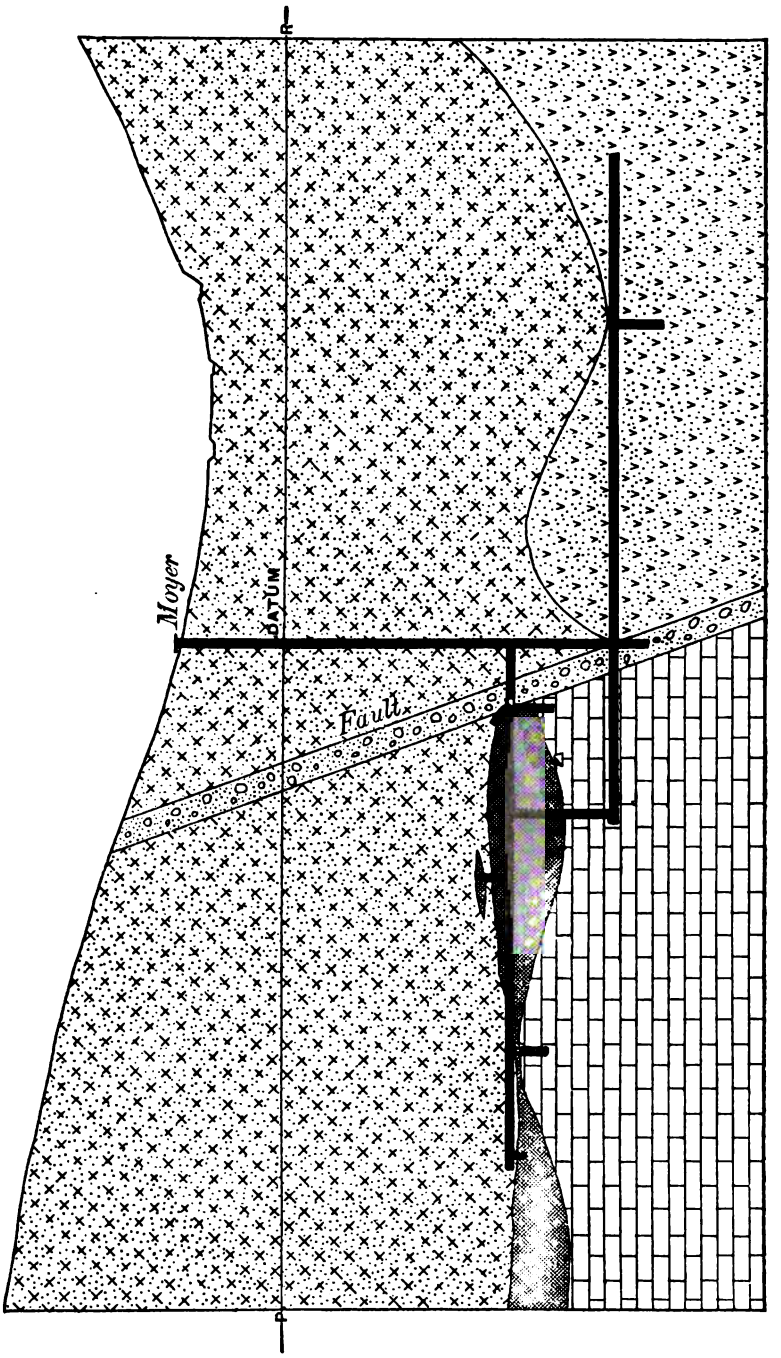
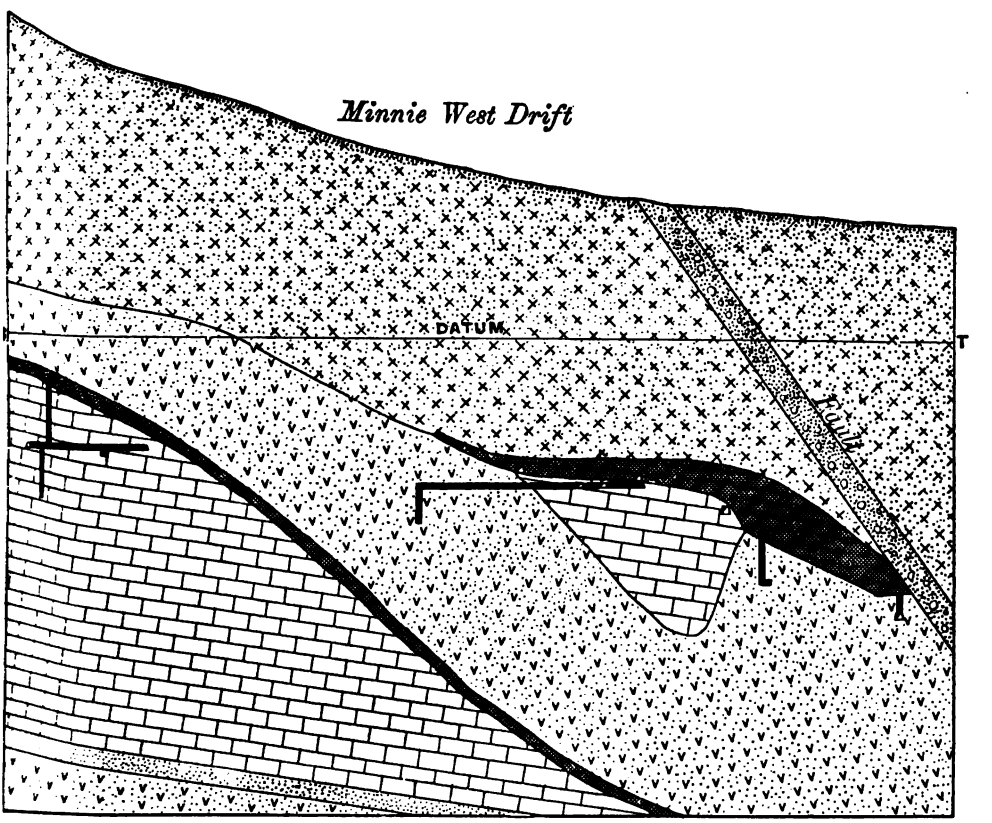



FIG. 5.

Section on line P R, Plate I.

5th, 10 feet of parting quartzite; 6th, 65 to 100 feet of gray porphyry, and then, white Silurian limestone. North of the Moyer fault, the strike is nearly north and south, and the dip from 15° to 10° to the east, being somewhat less towards the east. The line of outcrop of the vein, as marked upon the map, is also very nearly the eastern edge of the outcrop of the blue limestone. The course of the outcrop is at variance with that of the strike on account of the erosion of California gulch. The two most variable elements

FIG. 6.



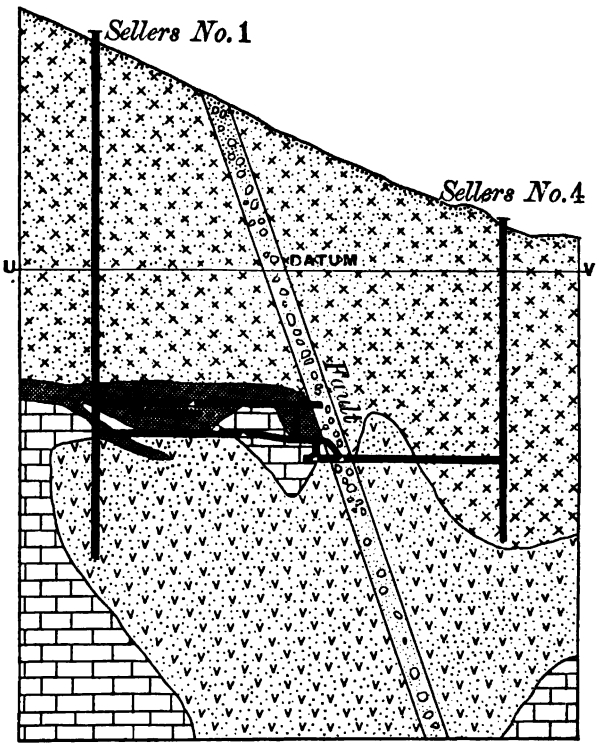

Section on line S T, Plate I.

in the columnar section are the two gray porphyry sheets, one above the vein and the other below the blue limestone. Near the outcrop the upper sheet does not extend much north of the Imes shaft. Going south its thickness increases to 160 feet just north of Califor-

nia gulch. From thence its thickness decreases again, and beyond the limits of the map rises into the overlying white porphyry. The lower sheet has a thickness of 65 feet at the northern limit of the map. Going south it increases to 100 feet near the middle of the map and then rapidly decreases towards the gulch.

South of the Moyer fault, and west of the Stone, the strata have about the same dip as on the north side, while in going to the east the inclination becomes gradually steeper, until at the eastern work-

FIG. 7.




Section on line U V, Plate I.

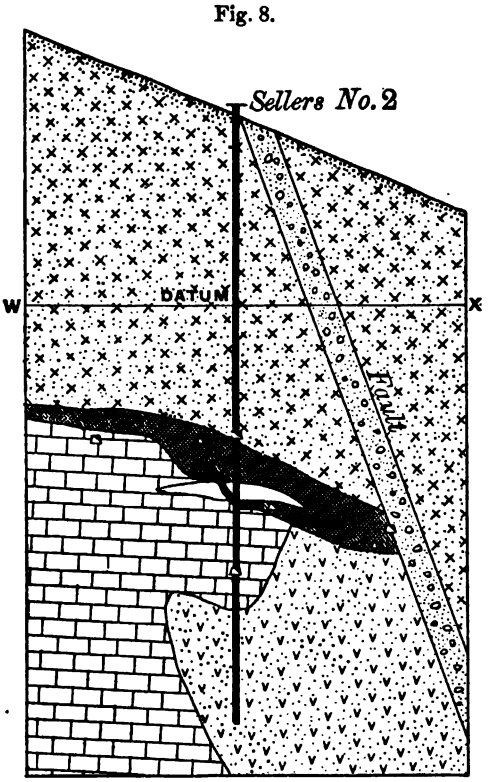
ings on the William Reddick and H. D.* claims it reaches 25° to 35°.

This simple formation is greatly complicated by an outflow of gray porphyry, which has broken through the blue limestone at a point somewhat east and south of the Moyer shaft. The stream

* The H. D. claim is just south of the William Reddick, and beyond the limits of the map.

runs from thence in a northwesterly direction across the south second level from the Moyer shaft into the Col. Sellers ground. Here it divides into two branches which, further on, in the Minnie ground, unite, inclosing an irregular mass of limestone, 100 by 200 feet, with its greatest dimension in an east and west direction, lying partly on the Sellers and partly on the Minnie ground. From the neighborhood of the Minnie shaft a feeble branch* is sent toward the north,

Fig. 8.




Section on line W X, Plate I.

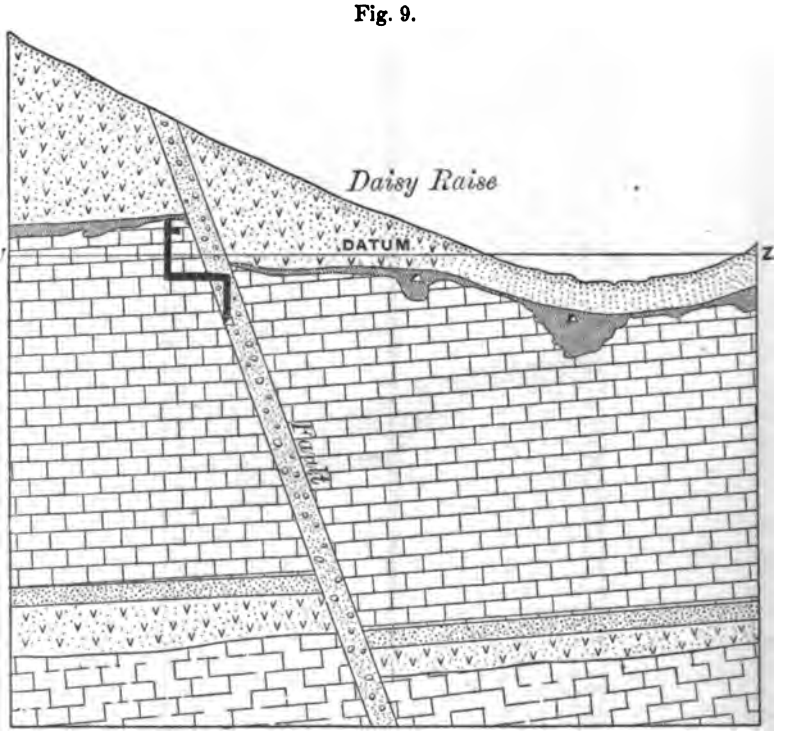
where it has been cut in the extreme north workings in the Sellers mine in the blue limestone. The main stream, from a point just west of the Minnie shaft, takes a southwesterly direction, rises to the upper surface of the blue limestone and spreads out on the contact.

* This branch is probably related to the gray porphyry developed in a vertical winze, 140 feet deep, in the Silver Cord Mine, 250 feet southeast of the Silver Cord shaft. The collar of the winze is 50 feet below the vein. This body of gray porphyry does not rise into the white porphyry, and does not appear in the limestone at this elevation immediately north or south of this point.

It forms the hanging wall of the vein throughout the south end of the Lime claim, Smuggler Cons. and Iron Hill Cons. Mg. Co.'s properties, A. Y. claim, and the whole of the Stone claim, and is the upper sheet of gray porphyry mentioned above.

The Moyer fault begins at the point of intersection of the California gulch cross-fault and the Dome fault, situated in California gulch 600 feet west of the Montgomery quarry, runs from thence northeast across the northwest corner of the Stone just south of

Fig. 9.




Section on line Y Z, Plate I.

the Beaudry shaft, thence in a nearly straight line through the Moyer shaft to the Mike fault. The throw is up to the north, and on section line Y Z is 40 feet; in the A. Y. it is small, passing through large stopes; on section line E F G H, Fig. 2, Plate II., it is 150 feet.

In the blue limestone north of the Moyer fault, there is a shallow secondary cross synclinal with its axis running north of east, making the strike of the vein N. 4° W. near the fault. South of the fault, there is a shallow secondary anticlinal with its axis running through

COMANCHE
COUNTY

IRON HIP CONE.
A
B
C
D

the Sequin* and H. D. shafts, parallel to the above, making the strike of the vein near the fault N. 18° W. The dip of the bed-planes of the blue limestone in the east workings of the Stone and William Reddick claims averages 25°. The dip of the contact from the fourth level north from the Stone incline to the Gilt Edge shaft No. 2 is 25°, and the dip produced at the same inclination cuts the Helen bore-hole at the upper surface of the blue limestone. With the north contact dipping at 11° and the south contact dipping at 25° and 150 feet difference of level in the two contacts at the east side line of the Minnie, and taking into consideration the true strikes and the inclination of the fault, about 70° to the south, a construction will give the two contacts the same elevation on opposite sides of the fault at the centre of the A. Y. claim.

The slight irregularity in the slope of the hill near the common end-line of the Stone and the Lime claims is due to the fault.

The north and south direction of the ore-channels in the Stone, La Plata, and Crownpoint claims probably resulted from the replacement being more active along crevices made in the blue limestone by the change of dip in this region.

The relation of the gray and white porphyry above the blue limestone and south of the fault, near the eastern edge of the map, is not clearly shown by the existing developments.

## Appendix.

The following analyses of samples from the Minnie mine are by William R. Boggs, Jr., Supt. Fryer Hill Smelter, Leadville, Colo.:

| | I. Galena. | II. Blende. | III. Pyrite. | IV. Mixture. |
|---|---|---|---|---|
| Pb, | 72.65 | 6.71 | 2.21 | 50.86 |
| Zn, | 5.66 | 55.08 | 14.24 | 12.86 |
| Fe, | 1.60 | 4.00 | 35.40 | 9.30 |
| S, | 15.66 | 32.44 | 44.76 | 24.50 |
| Ag, ozs. | (41.5) | (94.5) | (4.5) | (11.5) |
| " per cent. | 0.14 | 0.324 | 0.014 | 0 039 |
| Au, | tr. | tr. | | tr. |
| Residue, | 4.12 | 0.92 | 2.70 | 1.88 |
| Total, | 99.83 | 99.474 | 99.324 | 99.439 |

* The Sequin shaft lies west of the Dome fault. A section across this fault through the Crownpoint workings, Moynahan lease, Sequin and Only Chance shafts, gives a throw of 410 feet up to the east.

## *BIOGRAPHICAL NOTICE OF CHARLES O. THOMPSON.*

BY PHILIP W. MOEN, WORCESTER, MASS.

IT is with sincere regret that the members of the Institute will have heard of the death, on March 17th last, at Terre Haute, Ind., of Professor Charles O. Thompson, A.M., Ph.D., President of the Rose Polytechnic Institute of that city, and for many years previously the head of the Worcester County (Mass.) Free Institute of Industrial Science, and in 1881 and 1882 one of the managers of this society.

To us he was chiefly known by the excellent character of the work which he had performed, as a recognized leader among the technical educators of the country. He was a constant and interested attendant at our meetings, seeking to acquaint himself not less with all that was noteworthy in the practical attainments and developments of the branches of industry represented by our membership, than with such such facts as would be of service to him in shaping or guiding a wise course of instruction in the institutions of which he had charge. We shall not soon forget him, or the genial courtesy of his manner, or his ready words and thoughtful comments.

Charles Oliver Thompson was born September 25th, 1836, at East Windsor Hill, Conn., where his father, Rev. William Thompson, D.D., was professor in the Connecticut Theological Seminary, since removed to Hartford. The son was fitted for college under the late Paul A. Chadbourne, and entered Dartmouth College in 1854. He was graduated in 1858 with honors. In all the studies of his course he had maintained a high rank, but showed marked proficiency in chemistry and mechanical philosophy.

In 1861 he received the degree of A.M., followed by that of Ph.D. from his own college in 1879, and from Williams in 1880. In September, 1858, the year of his graduation, he became principal of the Peacham Academy, Vt., remaining in that position until November of 1864, though during that period he devoted several months to practical work as a surveyor and civil engineer.

Thus his experiences were developing the qualities which, later on, fitted him to carry out so successfully the plans of the thoughtful projectors of a new system of technical education, along a path before untrodden, but which the test of time and the indisputable proof of success have shown to be both wise and fruitful.

From 1864 until the early part of 1868, he was principal of the Cotting High School in Arlington, Mass. As the head of this school, which was a union of an existing academy, with its classical course, and of a public high school, in which the parents of the pupils desired for them a thorough practical training in English branches, Dr. Thompson's energy and sagacity developed a school which combined the best features of both. The highest requirements both of an English and of a classical high school, it is needless to say, were fully met.

In February, 1868, he was called to Worcester to become the principal of the new Free Institute of Industrial Science, and to occupy its chair of chemistry.

The general plan of the course of study had already been carefully set forth. To him was intrusted the arrangement of its details. The essential feature of the course which was new, was a prescribed amount of practical work in a thoroughly equipped shop connected with the school. The shop was to be managed as any other shop would be. Its products were to find sale in the open market; while the students, laboring without remuneration, were to be brought daily into contact with that class of work in wood and iron, with which they would have to do in actual business life.

The claims of the Free Institute to be the pioneer in this line of technical education will be readily conceded. To-day its rank as an educational institution is easily among the highest. Not so, however, when the young professor, then in his thirty-third year, assumed its direction. A splendid opportunity was opened to him, it is true; but it required a splendid man to embrace the opportunity aright, and to deal with its possibilities.

It is not too much to say of Dr. Thompson, that he realized to the full the great expectations which those who chose him had of him. He brought into play those faculties of perception and organization which he possessed in rare measure, and which previous training had done so much to render his tried and efficient servants. Immediately after his election to the honors and responsibilities of his new office, Professor Thompson went abroad and passed some eight months in close and careful study of the technical schools of Europe. The schools of Russia he was unable to visit, but enough was known of them and their methods to make their special features of great value to one engaged, as Professor Thompson was, in discovering what would be of service in the curriculum of the new school.

In November he was present at the opening of the Technical School, and his active labors with it began.

It has been said of him that his plans for the school were so carefully laid, his courses for study so wisely chosen, that in no case did he feel called upon to reverse his decisions regarding them.

In the midst of all the perplexities and difficulties attending the opening years of the school, his associates learned to know and to rely upon his wise counsels. His thoughtfulness for them drew them to him with a cordiality of affection not common to men in similar relations. From his students he always had such respect and confidence as his attainments and his singularly winsome personality could not fail to excite.

One faculty of Dr. Thompson was his clearness of insight into subjects of widely varying import, and an even more remarkable gift was his ability to convey to his hearers exactly that shade of thought which he had in his own mind. This gift, embellished by an extensive familiarity with all that is best in literature, was one of the chief secrets of his great success as a teacher.

The increasingly satisfactory results which attended the labors of Dr. Thompson and his associates could not fail to attract attention to the merits of the Worcester Institute. New institutions were started, embracing the salient features of its system. Others so far modified their previously adopted plans as to permit that judicious blending of theory and practice, which, under Dr. Thompson's guidance, had been demonstrated to be prolific of good results.

It was not strange that a man whose reputation as a technical educator had become national, should receive tempting offers to labor in new fields. At last, in April, 1882, Dr. Thompson accepted the position of President of the Rose Polytechnic Institute of Terre Haute, Ind. The school was founded as nearly as possible upon the plans of the Worcester school.

In July, 1882, Professor Thompson again went to Europe. Returning after an absence of eight months, he delivered his inaugural address at Terre Haute, March 7th, 1883, and remained as President of the Rose Polytechnic until his death.

It will not be out of place to rehearse here the principles laid down and followed at Worcester, and subsequently adopted for the Miller School in Virginia and the Rose Polytechnic at Terre Haute.

1. A manufacturing machine-shop, financially independent of the academic department, and yet so related to that department as to exemplify and make practical its studies.

2. Such an adjustment of study, recitation, and labor-hours as to make the above combination of discipline successful in a course of three years and a half.

3. A choice of course to be pursued; but, this choice once made, a rigid line of work to be followed out.

4. Articles made in the shop to compete in open market and unprotected competition with the same articles made in other shops, devoted solely to the purpose of manufacturing.

5. Thus to give the student at every step of his progress opportunity to see practical and intrinsically valuable work done, and to do it himself as soon as he should be able, while he would have all the time that peculiar sense of responsibility which can be induced only by a knowledge that something depends upon his work.

To these add the remarks of Professor Thompson in his inaugural address in Worcester in 1868: "It (the Worcester County Free Institute) fills a place hitherto unoccupied," and from an address delivered at Grand Rapids, Mich., December 31st, 1884: "In all the great schools that began before 1868, there were collections of apparatus and models, drawing-rooms and laboratories for the proper teaching of practical science, but there was no workshop worthy of the name. The mechanical arts were the last to be recognized in schools of engineering. The first school to embody in the course a thoroughly equipped and genuine workshop, was the Free Institute at Worcester, Mass., in 1868;" and we have a comprehensive view of the plan of technical education on which Dr. Thompson labored at Worcester and Terre Haute.

Members of the Institute who were present at the memorable debate on technical education, held at Philadelphia in 1876, at a joint session of our Society with the Society of Civil Engineers—a debate, the report of which, published in a special volume by the Institute, constituted one of the most valuable contributions ever made to the literature of this subject—have often recalled the impression produced upon that audience of eminent engineers by the clear, elegant, and instructive off-hand remarks of Professor Thompson, who rose upon invitation, a stranger to nearly all who were present, but "carried the house by storm," and was compelled by urgent calls to prolong his speech when he modestly intimated his fear of trespassing upon the time of the meeting. The circumstance shown in the printed report, that almost every subsequent speaker referred to something said by Professor Thompson, is significant

testimony of this impression. As a specimen of his felicitous and suggestive style, I cannot forbear to quote the following passage:

"It seems to me that there are three elements in all sound technological training: handicraft, technical training, and culture. There has been a surprising and gratifying unanimity of opinion on this point among the gentlemen who have spoken. The only question is, how these elements shall be combined.

"What is the object of technological schools? It is to produce the best possible raw material for skilled workmen. No school can impart the skill and good judgment which come alone from experience, and without which no man is a competent engineer.

"Another question with which a school has little to do is whether a youth shall be a superintendent or not. I take it that the Almighty makes superintendents. The precise kind of talent which enters into their characters is strictly an endowment.

"In this discussion some have held that the order should be handicraft, technics, culture; others culture, technics, handicraft; and others would arrange in other ways. But there is one objection to all these sandwiching methods. Practically we cannot hold our young men in training till twenty-five. They will go at twenty-one or twenty-two. The period of sharp acquisitiveness, the most precious part of school life, lies between sixteen and twenty-one. Now, which ever part of a boy's triune discipline for an engineering life is allowed to usurp that period to the exclusion of the others, that will be the dominant force in his after-life. If culture, then practice will suffer; if practice, culture will suffer. Either part will be, as it were, attached to, or subordinated to, the one which 'rules the favored hour.' Hence, it seems to me that all possible culture should be secured before a student begins his technological course, and that it should be looked to ever after. It must not be forgotten that culture is a result, or rather a growth. All we can do is to prepare the soil. The plant will assuredly grow. Perhaps, too, the best and only useful culture is to be looked for in the life for which any school training prepares a man; for I take it, we are not now speaking merely of the cultivation of the æsthetic part of man, but of that discipline of the judgment, awakening of the imagination, sharpening of perception, repression of conceit, and elevation of motive, which constitute a serviceable and efficient man of refined taste and unquestionable integrity and courage.

"Let us secure as large a foundation as possible in general knowledge before the beginning of the technical course, and not lose sight

of the bearing and relations of all knowledge during this course. But let us blend technics and handicraft in the technological course."

In his addresses on public occasions, Dr. Thompson never failed to impress his hearers with his broad scholarship, and with a sense of his high ideals of life. The commencement addresses to the graduating classes were beautiful in diction and noble in thought. "The great woe of practical men," he once said, "is to underrate other kinds of knowledge. Value knowledge for its own sake." And again: "Remember that you cannot bind others by your own rules, and that misfortune, weakness, and even sin, deserve mainly your active sympathy." At another time: "Whatever you do, achieve, enjoy, or are, there is something more to do, something more to achieve, something holier to be;" and, "I have been sometimes overwhelmed with the thought that all learning is worse than useless which is not accompanied and controlled by simple faith in God and in our fellow-men."

In the brief time which he lived in Terre Haute, his devotion to his new charge had done much to make it a power in its Western field. Its success was assured from the start. At Terre Haute, as in Worcester, Professor Thompson's time and thought were not confined to his school merely. Such portions of either as could be spared, were freely given to the church with which he was connected, to his city, and to the amenities of its social life.

One can but mourn that a life so full of energy and usefulness should have been so early closed; but the works which he wrought will live after him to his honor, and with us will remain the memory of a life nobly lived.

## *THE "CENTENNIAL" AND "LOTTA" GOLD PROPERTIES, COAHUILA, MEXICO.*

BY DR. PERSIFOR FRAZER, PHILADELPHIA, PA.

THESE properties, owned by Mr. William A. Butcher, of Philadelphia, are in the Panuco Mountain, which lies about thirty miles southwest of the town of Candela. It is a granite which penetrates the surrounding limestones and contains the famous copper-mine to which it gives its name.

This mine, which is the property of a company in Philadelphia, has long been known to produce gold as well as copper from almost all its parts; and in corroboration of this be it said, that the undersigned has washed gold from a number of places where the works of the mine or natural sections had exposed the decomposed granite to view in the state of kaolin.

It is well known that these junction- or contact-planes between two different formations are often the lodging-places of much free-milling gold, which through fissures are sometimes carried long distances perpendicular to the strata and into the interior of the formation.

The structure of the Panuco Mountain, with its outlying spurs and adjacent foot-hills, forms a most instructive and unusual study. At a rough guess the area covered by this mountain will equal, perhaps, twenty-five to thirty square miles; but its singular feature is the intimate welding together of two formations into one topographical unit.

The lines of division between the granite and the calcareous sandstone are of such complicated character that they could not be mapped on a small scale. Unlike the majority of such contacts, the divisions between formations are not always marked in the Panuco Mountain by gulches, valleys, and streams (or the dry beds of the latter), but in the portion of the mountain which lies south of the Panuco copper mine, the lines of junction of these formations cross the gulches and promontories, and, in some instances, cannot be traced by any such topographical features.

The house of the Panuco copper mine is 3742 feet above ocean-level (by rough barometric observation), and the gold-mine about to be described is 235 feet above this, and about two miles distant,

over a crest of the composite mountain, from which ridges and gulches lead down to the south. (This latter is, however, a guess from memory.)

The position of the "Centennial" and "Lotta" gold properties

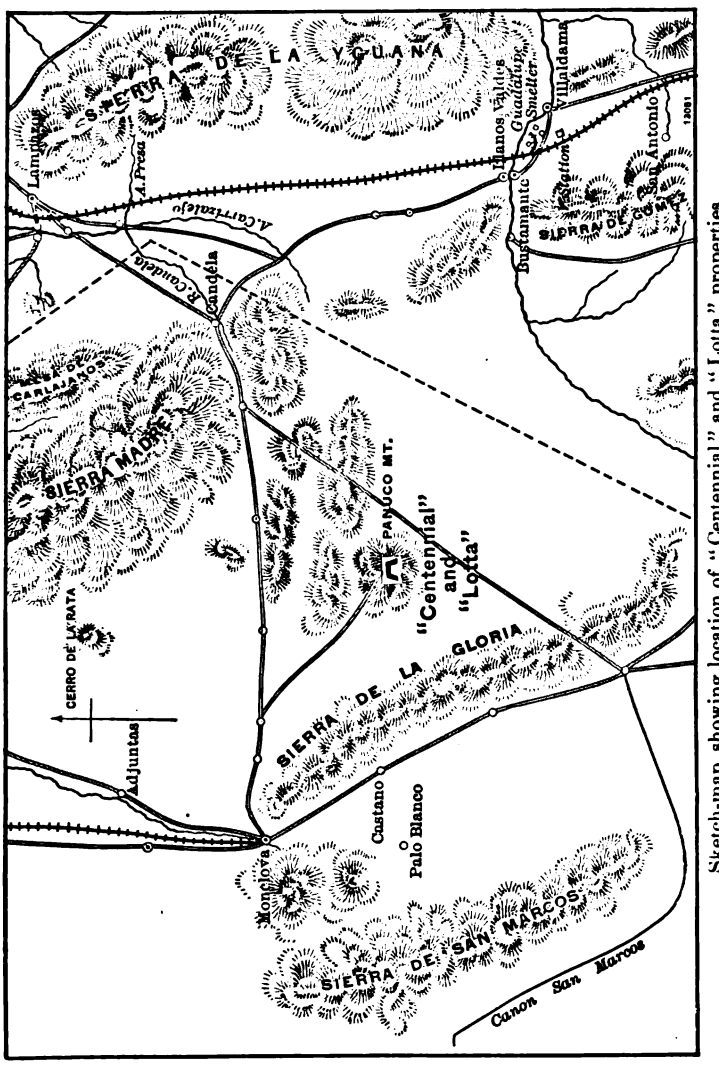


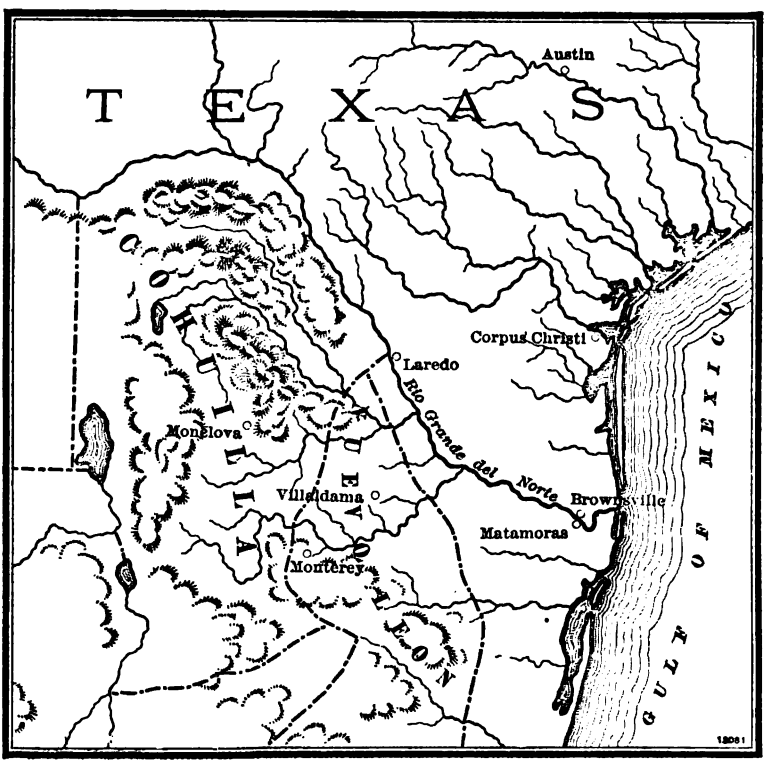

Fig. 1. Sketch-map, showing location of "Centennial" and "Lotta" properties.

with reference to the cities and railroads of Northern Mexico, is given in Fig. 1, which is a part of the general map taken from D. Nigra de San Martin, and already printed in these *Transactions*, vol. xii., p. 568, in connection with my paper on "Certain Silver

and Iron Mines in the States of Nuevo Leon and Coahuila." Fig. 2 shows upon a smaller scale the whole of these two States. Fig 3 is part of a special contour-map of the locality, made by the writer.

The "Centennial" prospect-pit lies on the east side of a narrow ravine which, just at this point, very nearly divides the granite in that direction from the calcareous sandstone to the west (see Fig. 3). A hole, about eight feet deep, has been sunk through a compact feldspathic granite, exposing, in its northeast wall, five small veins.

FIG. 2.

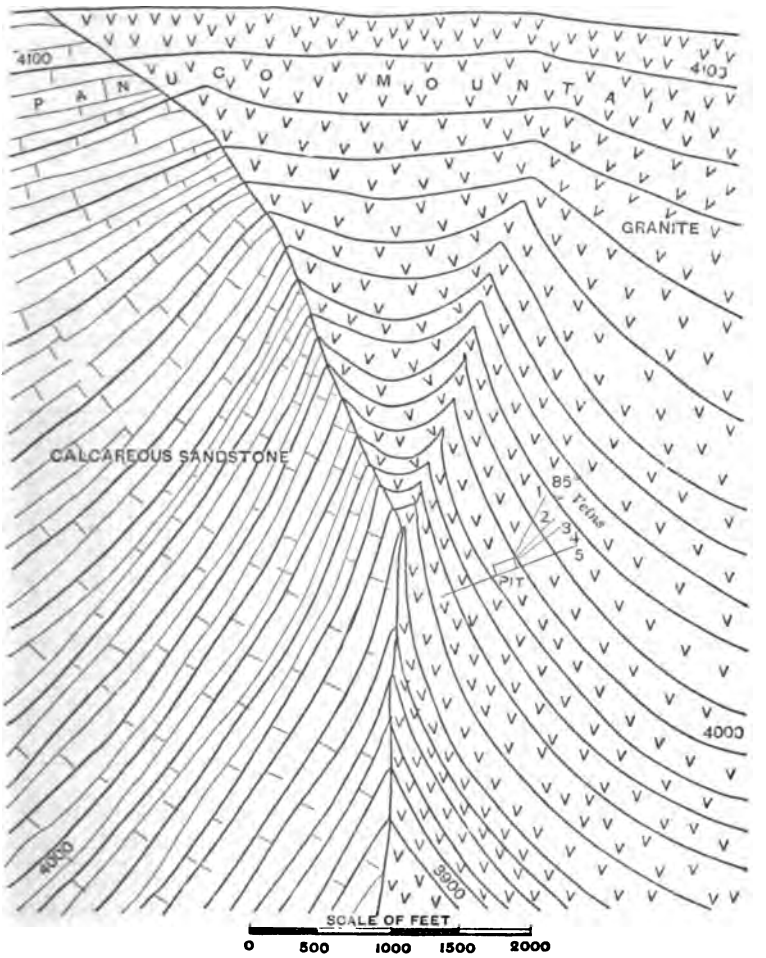



The Rio Grande Region.

The northwesternmost of these five veins is about five inches wide, including as part of it one inch of ferruginous material, and dips about E. 30° S.—85° (strike N. 30° E.). The second, to the southeast, strikes N. 20° E.—vertical. The third strikes E. 40° N.—nearly vertical, is 1½ inches wide, and has a pay-streak of ¼-inch. The fourth and fifth are close together, and are parallel to the S.E.

wall of the opening; they strike E. 20° N.—vertical, or nearly so. They are about three inches apart in the exposure, and may be considered one vein divided by a parting. The ferruginous pay-

FIG. 3.




Rough Sketch-map of Auriferous Veins on Panuco Mountain.

streak of the northwesternmost of the two is about one-half inch in thickness, and of the southeasternmost two inches. The writer deemed it of interest to examine each of these veins separately, for the purpose of ascertaining which of them carried the gold or the greater part of it.

The lower and especially the northwest face of the pit is stained with copper salts, which have been extracted by rains and deposited by evaporation on the walls. It is most probable that these veins come together at no great depth below the surface, and form one vein, but they are considered separately in this paper. The following table will give the characteristics of these ores. The northwesternmost is called No. 1; the vein next adjacent, and to the S.E., No. 2; the next following, No. 3; and the two nearest the S.E. wall, No. 4; No. 5 and No. 6 are specimens, said to have been taken from the bottom, and furnished the writer for analysis by Mr. W. A. Butcher. No. 7 is a copper ore furnished by the same.

Nos. 1, 2, 3, and 4 were taken by the writer from the veins in place, and represent in his judgment a fair sample.

*Gold Ores from the "Centennial" Prospect of Mr. W. A. Butcher, at Panuco, Coahuila, Mexico, Analyzed in my Laboratory by Messrs. C. Hanford Henderson and Richard D. Baker.*

| Localities. | Specific Gravity. | Gold. | | Silver. | | Copper. | | Total Value. |
|---|---|---|---|---|---|---|---|---|
| | | Ounces per ton. | Value, $20.67. | Ounces per ton. | Value, $1.29. | Per cent. | Value, 14¼ cts. | Gold, silver, copper. |
| 1. N. W. Vein | 3.75 | 12.20 | $252.17 | 15.2 | $19.61 | 1.18 | $3.36 | $275.14 |
| 2. Second Vein | 3.35 | 0.40 | 8.27 | .6 | .77 | trace. | ..... | 9.04 |
| 3. Third Vein | 2.75 | 0.20 | 4.13 | .8 | 1.03 | trace. | ..... | 5.16 |
| 4. Fourth and Fifth Vein | 2.91 | 0.20 | 4.13 | 1.0 | 1.27 | trace. | ..... | 5.42 |
| 5. Said to come from bottom. From Mr. Butcher | ... | 18.40 | 380.33 | 11.0 | 14.19 | 11.23 | 32.00 | 426.52 |
| 6. Said to come from bottom. From Mr. Butcher | ... | 9.70 | 200.50 | 9.8 | 12.64 | 12.42 | 35.39 | 248.53 |
| 7. Furnished by Mr. Butcher | ... | 7.30 | 150.89 | 9.9 | 12.77 | 12.44 | 35.45 | 199.11 |

It is evident from an inspection of the above table of analyses that the "pay" of these minute veins is mainly confined, near the surface, to Vein No. 1. This is also the vein or stringer which most nearly conforms to the line of demarcation between the formations, and doubtless bears some relation to it.

The method of analyzing each of these veins gives the most impartial view of their comparative merits, and therefore of the aggregate richness of the belt. It is not intended that these assays of certain barren parts of the main ore-bearing rock should be interpreted as evidence against the productiveness of that rock.

The ores of the different veins are all similar in character and vary only in the amount of gold and auriferous sulphides present.

The northwestern vein, marked No. 1 on the contoured sketch-map, Fig. 3 (and containing by far the richest ore), consists of a granitic gangue, carrying pyrite chalcopyrite, possibly, some chalcocite and an hydroxidized portion (principally iron hydrates) resulting from the decomposition of the sulphides. The gold is distributed through this mass, either as free gold or as a constituent of the sulphides. The analysis shows $252.17 gold, $19.61 silver, and $3.36 copper; making a total value of $275.14 per ton of 2000 lbs. At the time of my visit the state of the exploitation was such that while the veins were well-defined and unquestionably in position, rendering the samples of ore selected fair representatives of the portions examined, there was no development to make a more comprehensive examination possible, outside of the shallow pit before mentioned. Their constancy and coalescence in depth or horizontal extension have not, therefore, been *proved* by actual exploration, but from the analogy of other metalliferous veins in similar formations, it is safe to assume that the same conditions hold, at least within moderate distances of the opening. The calculation of the amount of ore, not actually in sight but *probably* obtainable from that portion of the northwest vein immediately contiguous to the prospect pit, is made on this assumption.

There would be in each hundred feet of stoping-ground and one hundred feet on the strike, thus exposed, 4166.6 cubic feet of ore ($5 \times 1200 \times 1200 \div 1728$); which at a specific gravity of 3.75 would represent 487.5 tons of ore. Assuming the value obtained from the analysis (1), this block would represent a value of $134,130, and each additional hundred feet of stoping-ground and like amount along the outcrop exposed, the same conditions maintaining, would increase the resources of the mine by the above amount.

In view of the low value of the other small veins, of their exceeding narrowness, and still more of their probable union in depth with the first and large vein, it would hardly seem desirable to enter into any calculations in regard to their probable value.

A fresh set of samples were obtained by Mr. W. A. Butcher during a trip by him to these properties, during the early spring of 1885.

Of the amounts which were brought home by him (perhaps 200 lbs.), I carefully averaged and sampled a sufficient quantity to give reliable minimum results as to the value of each gold outcrop. The "Centennial" and "Lotta" thus sampled gave to the assay of Mr. R. D. Baker, B. S.:

| | Specific Grav. | Gold. | | Silver. | | Copper. | | Total Value. |
|---|---|---|---|---|---|---|---|---|
| | | Oz. per ton. | Value —$20.67. | Oz. per ton. | Value —$1.29. | Units. | Value per unit, $2.84. | |
| "Centennial" | 2.85 | 4.4 | $90.94 | 10.0 | $12.90 | 6.12 | $17.38 | $121.22 |
| "Lotta" | 2.87 | 4.2 | 86.81 | 10.7 | 13.80 | 3.65 | 10.36 | 110.97 |
| Small fragment of chalcopyrite | ..... | 3.5 | 72.35 | 7.5 | 9.67 | Undet. | ..... | 82.02 |

Considering the care taken that the mass analyzed gave the real mean of the material taken by Mr. Butcher from each mine, the above results are encouraging.

The "Lotta" is said to lie about 1000 yards N.E. (on the strike of the auriferous vein) from the Centennial, which latter is the name applied, after my departure, to the opening which is above described.

The following list contains, in tabulated form, the results of analyses made by other chemists, and given to me by Mr. W. A. Butcher. It needs no further explanation.

In regard to the supply of water for mine uses, the following letter from Dr. H. B. Butcher to his brother is added in a foot-note.* It contains also Dr. Butcher's views of the structure and value of the ore-veins.

Dr. Butcher has spent many years in the part of Mexico which contains this property, and was the organizer, and for some years the resident manager, of the company which owns the celebrated Panuco

---

*PHILADELPHIA, July 9th, 1884.

WILLIAM A. BUTCHER, ESQ., PHILADELPHIA, PA.:

DEAR SIR: The Panuco Gold Mine, of which you took possession in April last, is situated some thirty miles west from Candela, two and one-half miles southwest from Panuco Copper Mine, and about three miles from old Spanish hacienda, where there is a permanent stream of water.

Your vein is composed of three perpendicular veins, each two to three inches wide. Your prospect-shaft, twenty to twenty-five feet deep, shows the three stringers its whole depth. The stringers appear to be verging together, which, in all probability, will join in a few more yards of depth.

The ore is a sulphide of copper, carrying some $250 to $300 of gold and silver per ton.

This vein we consider in our district a first-class prospect. Would be much pleased to see the mine when developed some thirty to fifty feet more in depth.

Very truly yours,

H. B. BUTCHER.

| Description. | Analyst. | Date analyzed. | Ounces of gold per ton. | Value at $20.67 per ounce. | Ounces of silver per ton. | Value of silver. | Total value, gold and silver. |
|---|---|---|---|---|---|---|---|
| "Centennial," collected by W. A. Butcher, . . . . | Riotte. | May 16th, 1883. | 10.94 | $226 15 | 13.86 | $17 88*a* | $244 03 |
| " " " . . . . | Justice. | July 9th, 1884. | 12.65 | 253 00 | 18.50 | 20 01*b* | 273 01 |
| " " " . . . . | " | " | 12.41 | 248 27 | 17.40 | 18 70*b* | 266 97 |
| " " " . . . . | Williams. | Dec. 17th, 1884. | 5.96 | 123 19 | 7.95 | 8 58*c* | 131 77 |
| " " " . . . . | " | Dec. 20th, 1884. | 5.70 | 117 81 | 8.50 | 8 98*c* | 126 79 |
| " " E. Clark, Jr., . . . . | E. Clark, Jr. | Dec. 28th, 1884. | | 180 00*e* | | 10 00*e* | 190 00*e* |
| "Lotta," collected by W. A. Butcher, . . . . | E. S. Campbell, Jr | April 10th, 1885. | 5.00 | 103 35 | 10.00 | 10 80*c* | 114 15 |
| " " " (gangue), . . . | " | April 13th, 1885. | 1.10 | 22 73 | 10.30 | 11 12*c* | 33 85 |
| "Centennial," collected by W. A. Butcher and E. Clark, Jr., . . . . | " | April 18th, 1885. | 6 00 | 124 02 | 7.50 | 8 02*d* | 152 04 |
| "Centennial," collected by W. A. Butcher and E. Clark, Jr., . . . . | " | " | 9.00 | 186 03 | 13.00 | 13 91*d* | 199 94 |

*a* Value of silver at date of analysis. (Coin value, $1.29 per ounce.)
*b* " " " " @ $1.10 "
*c* " " " " @ $1.08 "
*d* " " " " @ $1.07 "
*e* Neither the number of ounces of the gold and silver nor their current values per ounce were given, but only the total values.

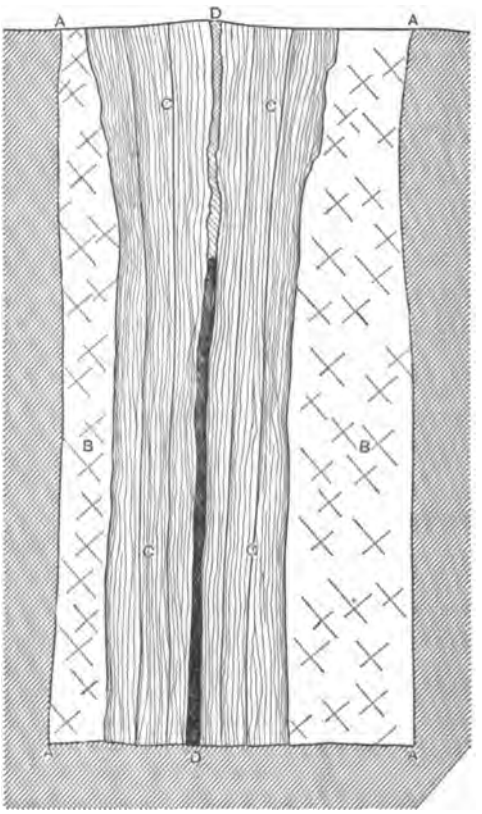
Copper Mine, situated in the same mountain. His views of the state of facts, always temperate and thoughtful, are entitled to every respect.

## Discussion.

Ellis Clark, Jr., Philadelphia, Pa. (Communication to the Secretary): Having personally examined the properties described in this paper, I can corroborate in every particular the account of Dr. Frazer. The accompanying sketches, made by myself, exhibit the structure of the veins as explained in the paper.

Fig. 1 is a rough sketch of the Centennial vein as it was exposed in December, 1884.

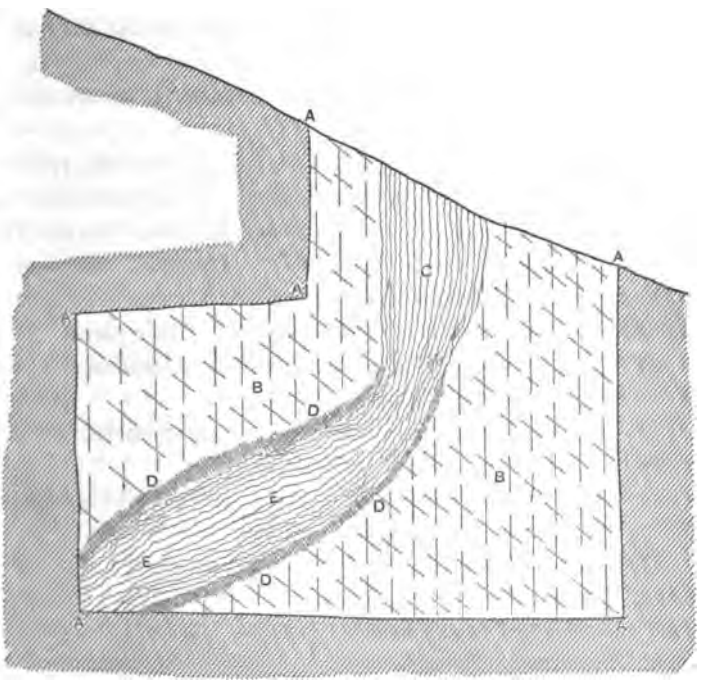
Fig. 1.




Centennial ore-vein, Coahuila. A, A, A, A, walls of excavation (12 ft. deep); B, B, granite country-rock; C, C, vein-matter (decomposed granite) 2 ft. wide; D, D, streak of copper pyrites, carrying gold, 1 inch wide. Strike, N. 38° E.

Fig. 2 is the Lotta vein as sketched in March, 1885.

FIG. 2.




Prospect pit on Lotta vein, Coahuila. A, A, A, A, A, opening on vein, 5 ft. deep, 6 ft. long; B, B, granite walls, somewhat decomposed, showing cleavage planes; C, decomposed vein-material; D, D, decomposed pyrites, colored with copper, carrying $91 gold per ton; E, E, vein-material (reddish cherty and clayey rock) carrying $34 gold per ton. The vein is 1 ft. to 2 ft. thick; strike, S. 45° E.; dip, 15° to 20°. The hanging-wall, D, is 3 inches thick; the foot-wall, D, 2 inches.

I think of nothing else which I could add to Dr. Frazer's description of these properties.

## *QUICKSILVER-CONDENSATION AT NEW ALMADEN.*

BY SAMUEL B. CHRISTY, UNIVERSITY OF CALIFORNIA, BERKELEY, CAL.

THE present paper is a continuation of a study of the reduction-works of New Almaden, the first part of which was published under the title "Quicksilver-Reduction at New Almaden," in the *Transactions* of this Society, vol. xiii., p. 547.* Frequent reference will be made to some of the data there given.

The following is an outline of the contents of this paper:

I. Condensing appliances used at New Almaden:
   *a.* Brick condensers,
   *b.* Iron condensers—flues and "water-backs,"
   *c.* Glass and wood condensers,
   *d.* Friction-condensers—filters and revolving screens,
   *e.* Flues, towers, and chimneys.
II. Analysis of condensing-systems.
III. Temperature of condensers.
IV. Product of condensers.
V. Treatment of soot.
VI. Losses of treatment:
   *a.* Nature of losses,
   *b.* Composition, weight, and volume of dry gases,
   *c.* Volume of wet gases,
   *d.* Specific weight of quicksilver vapor,
   *e.* Vapor-loss at various temperatures.
VII. Comparison with New Almaden practice.
VIII. Comparison with results at Idria, Austria.
IX. Comparison with results at Almaden, Spain.
X. Future improvements in quicksilver-condensation.

### I. CONDENSING APPLIANCES.

The complete condensation of mercurial fumes in a large way presents numerous practical difficulties, familiar to all who have had to retort amalgams. In condensing the quicksilver-fumes discharged

* Also published in part, *Eng. and Min. Journal*, vol. xxxix., pp. 156-158, 171-175, 190-192, and *Mining and Scientific Press*, July and August, 1885.

from a roasting-furnace, the problem is much more difficult. The quicksilver-fumes furnish often less than 1 per cent., by volume, of the products of combustion with which they are mixed. Even the weight of the quicksilver is inconsiderable, compared with that of the gases which pass through the condensers. At New Almaden it is only about 2 per cent of the latter.

These facts add greatly to the difficulties of condensation. For, in the first place, more heat must be abstracted from the fumes in order that the quicksilver may be liquefied. Next, the whole volume of the gases must pass through the condensers at a certain velocity, in order to maintain the draft of the furnace. The minute condensed globules of liquefied quicksilver are likely to be carried off in the form of *mist*. The gases which escape from the condensing system, are necessarily saturated with quicksilver *vapor* at the temperature of escape. Then there is the ever-present mercurial soot, which requires separate treatment. The quicksilver itself is ready to escape from any crack or crevice of the condensers, either as a liquid or as vapor. As a liquid, on account of its density, it worms its way into foundations and walls; as a vapor, it is ready to escape into the air, should any cause temporarily reduce the draft of the furnaces. Finally, as soon as the condensers become cool enough to act effectively, they are attacked by the dilute sulphuric acid formed from the oxidation of the sulphurous acid in the fumes. This agent slowly attacks and destroys almost every material out of which the condensers can be made. The use of lead is of course out of the question, as that would be attacked by the quicksilver itself.

The system in use at New Almaden is based on the following well-known principles:

1. Cooling of the furnace-fumes by contact with large radiating surfaces exposed to air and water.

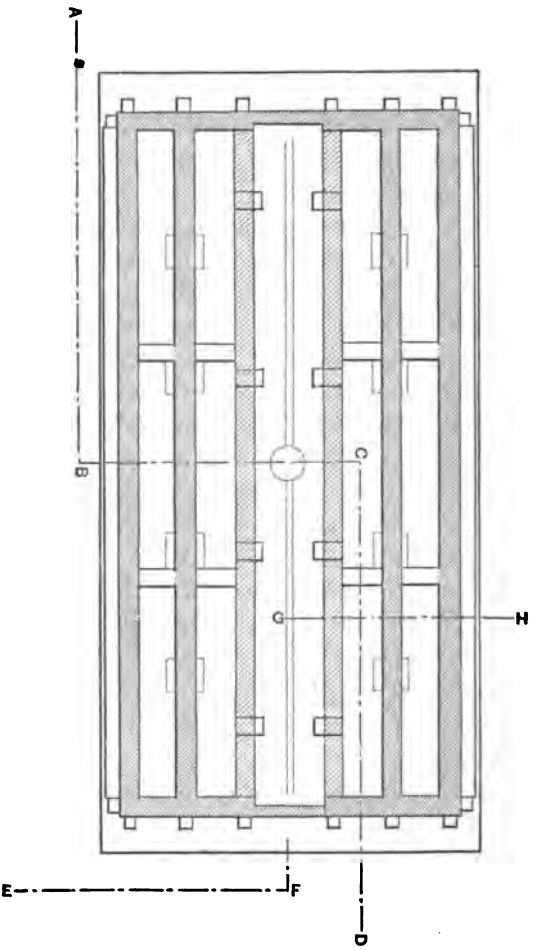
2. Sedimentation of the condensed quicksilver particles in enlarged chambers where the velocity of the gaseous mixture is reduced.

3. Constant exposure to friction-surfaces, cross-currents and vortex-motions to remove the globules of metal by calling into play the force of adhesion.

*a. Brick Condensers.*—With the old intermittent furnaces large sedimentation-chambers were considered of first importance, and very properly, for between the roasting-periods the condensers had time to become well cooled, and sedimentation-volume was thus the great need. Hence the condensers used with these furnaces were

built like those of the ancient Idria furnaces, in continuous blocks of masonry. Partition-walls with holes alternately at the top and bottom served to deflect the current up and down through the series.

FIG. 1.




Plan of Condensers.

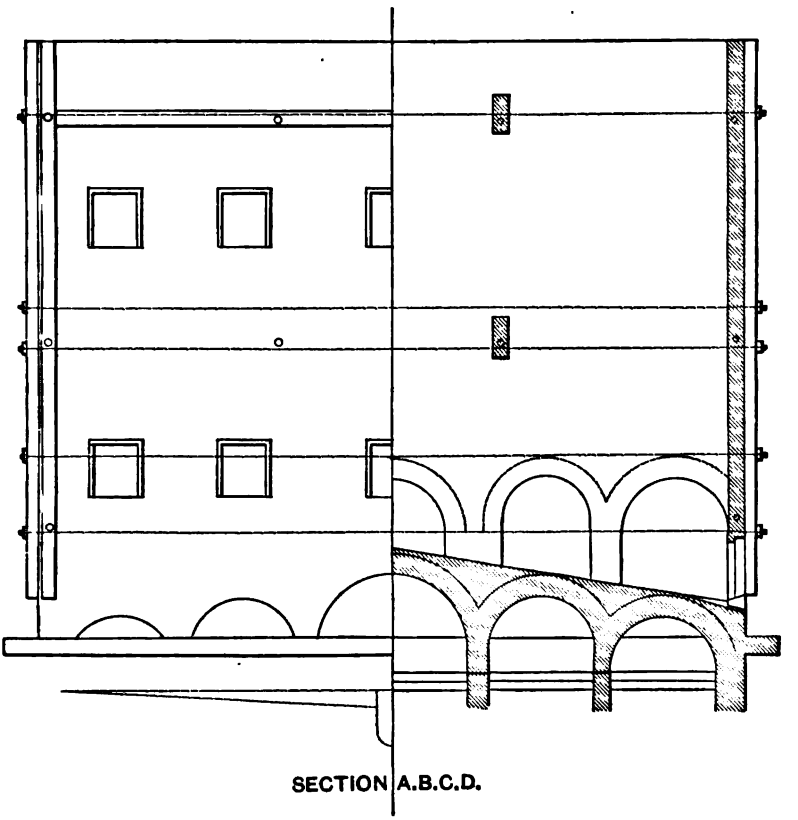
Scale $\frac{1}{8}$ in. = 1 ft.

This system was thought to give satisfactory results with the intermittent furnaces, although the condensers were often poorly built and the alternate exposure to heat and cold filled them with cracks, causing loss of metal, and salivation of workmen.

As soon as the continuous furnaces came into operation and poured

a steady stream of fumes into the condensers, the latter were found to be utterly insufficient. No longer given time to cool off, the latter became so hot that metal was deposited only in the last members of the series. Additional cooling-surface was obtained by knocking out the end walls of every third condenser, in some cases every alternate

FIG. 2.



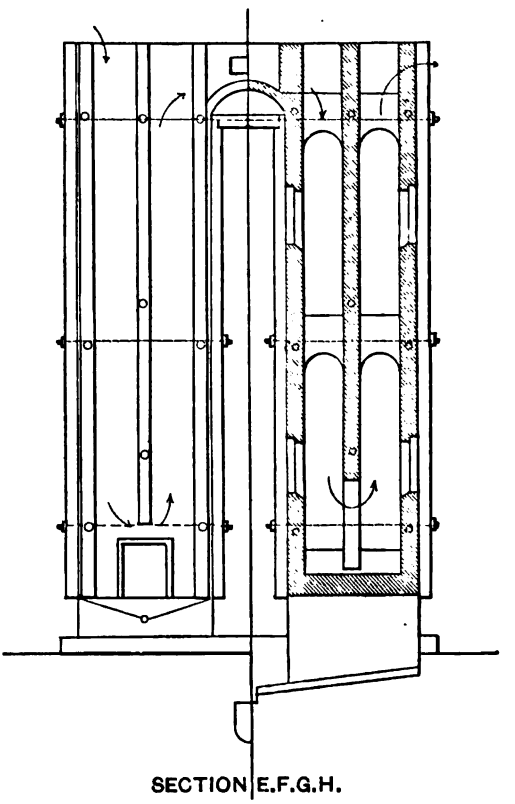

Side-elevation and Longitudinal Section of Condensers (see Fig. 1).

Scale $\frac{1}{8}$ in. = 1 ft.

one. The remaining condensers were connected together at the top, and the resulting system with less sedimentation-volume, but more cooling-surface, gave better results than the old one. After this, when, owing to the attack of acid waters, the condensers had to be rebuilt, they were made with a view to larger cooling-surface, and, with the advantage of experience, more care was bestowed on the details of construction.

The plan, sections, and elevation of two condensers formed on this plan, are shown in Figs. 1, 2, and 3. It will be seen that each condenser is a tall, narrow structure divided by a vertical partition-wall into two compartments. The fumes enter the condenser near the top, pass down the compartment on that side, and out through the arched passages at the bottom of the partition-wall into the other compartment, up which they pass to be discharged into the next one of the

FIG. 3.




End-elevation and Vertical Cross-Section of Condensers (see Fig. 1).

Scale $\frac{1}{8}$ in. = 1 ft.

series. Formerly the condensers were connected at the tops by brick necks or flues. Recently, however, earthenware and iron pipes are used for the purpose, and give more cooling surface.

The tops of the hot condensers are sometimes made of cast-iron plates which are used as drying-floors for damp *tierras;* in other cases they are topped over with flat arches of brick. The floors as

shown in section *CD*, Fig. 2, have a slope of 10° from the centre to either end, so as to shed the condensed metal to the drain gutters. The floors are brick, closely laid in the most careful manner, then a layer of cement. A heavy coat of asphalt is laid on this in all but the hottest condensers. Man-holes, 2 feet square, are left in the end-walls near the floor of the condensers, so that they may be cleaned at intervals. In the hot condensers, these holes are closed by iron plates, luted tight with clay and ashes. In the colder condensers, containing acid waters, iron is out of the question, and ordinary glass window sashes are used instead.

These brick condensers are arranged in a series so that they stand side by side with an air-space between each pair; the ends of all being in the same planes. The drain-gutters before mentioned pass the whole length of the series on both sides and receive all the quicksilver that flows from the ends of the condensers. The gutters are of brick, lined with cement and asphalt, and have sufficient grade to discharge the product of the condensers into the boxes and pipes which lead it to the weighing- and bottling-room belonging to each furnace.

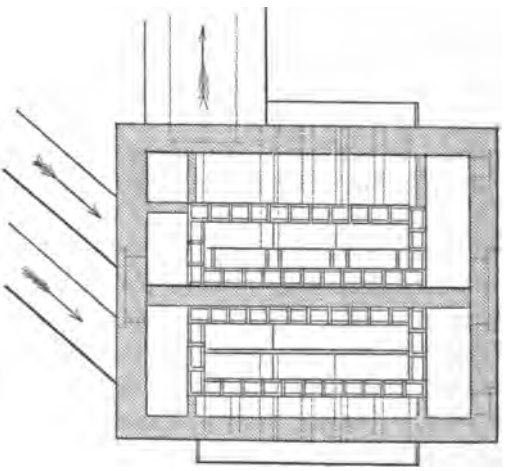
A combined brick condenser and drying-chamber for tierras is connected with the intermittent furnace No. 6. It was shown in Plate II. of my preceding paper. It differs from those just described in having two vertical chambers which are filled with tierra ore from above and discharged from below upon the floor in front of the discharge-ports. The hot fumes from the furnace circulate about these ore-chambers, and impart much of their heat to the ore which they contain, thus adding to the efficiency of the condenser. The hot ore, after being drawn, is spread out on the floor of the discharge ports, and the moisture rapidly evaporates.

An improved form of this device is shown in Figs. 4, 5, and 6. This forms a part of the condensing-system of No. 3 furnace. Here the drying-chamber is provided with shelves, resting on iron cross-bars. The tierras lie upon the shelves, much as they do in the roasting-furnaces. The method of drawing and discharging the ore is evident from the figure. The hot fumes from the furnace pass all around these drying-chambers, thus heating their contents. The steam generated from the moisture in the ore is allowed to escape to the open air through flues built in the hollow wall of the drying-chamber.

The leakage of quicksilver fumes through the walls of the brick condensers, and the permeation of the foundations by the liquid

metal are practically overcome by the care taken in constructing these new condensers. The condensers are always underdrained, and inclined iron plates, protected by coal-tar, are placed in the foundations. On the other hand, brick condensers can not be regarded as very effective cooling agents. The brick is among the worst conductors of heat, and it is found unsafe to build the walls thinner than nine inches. Besides, the mortar is slowly attacked by the acid fumes; gypsum and other sulphates being formed. These salts crystallize between the bricks, so that in some cases the walls of the older condensers have been so bent out of shape by this cause as to be

FIG. 4.



SECTION A A.

Condenser and Drying-Chamber (see Figs. 5 and 6).

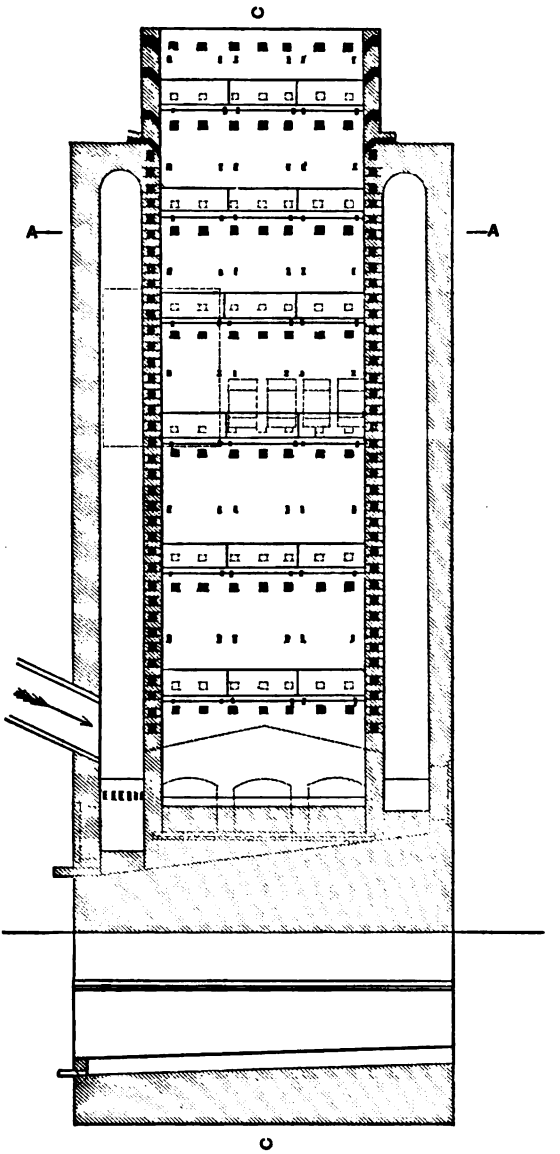
Scale $\frac{1}{8}$ in. = 1 ft.

unsafe. The bricks themselves are often attacked, and some of the outside walls of the old condensers are whitened by thick crusts of sulphates.

In order to protect the masonry from the attack of the acid-fumes, Mr. Randol has recently had them painted inside and out with a heavy coat of a hot mixture of asphalt and coal tar. This coating appears to be very successful when applied to new condensers, but it is difficult to make it adhere to walls already saturated with effloresced salts. In the very hot condensers it is inapplicable, but also unnecessary.

In spite of the numerous disadvantages of brick condensers,

FIG. 5.

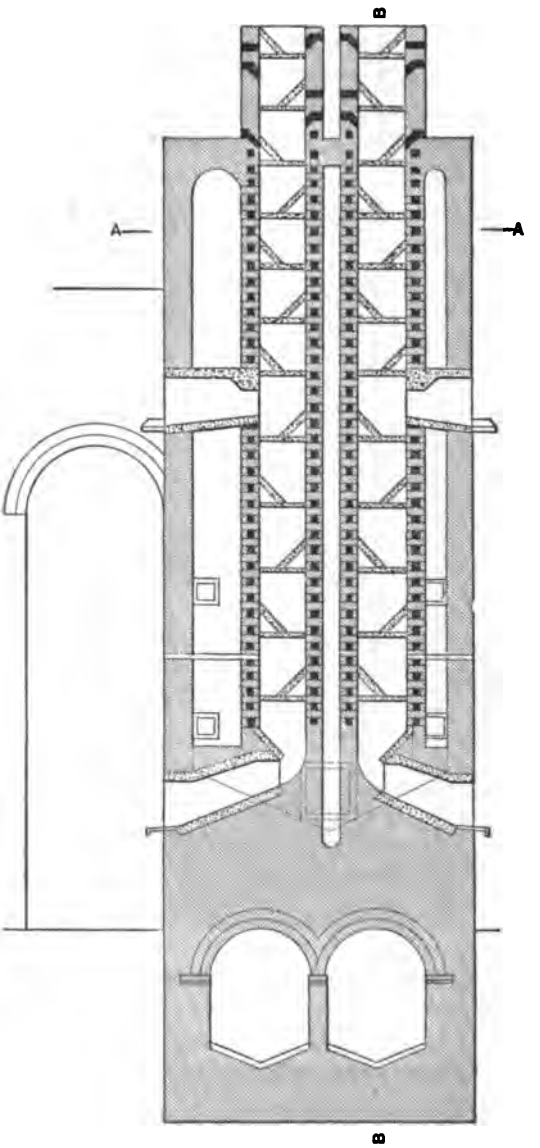



SECTION B B.

Condenser and Drying-chamber (see Figs. 4 and 6).

Scale $\frac{1}{8}$ in. = 1 ft.

FIG. 6.




SECTION C C.

Condenser and Drying-chamber (see Figs. 4 and 5).

Scale $\frac{1}{8}$ in. = 1 ft.

nothing has yet been found to replace them as sedimentation-chambers, and when they receive hot fumes still above the dew-point they suffer very little from corrosion.

*b. Iron Condensers.*—In view of the inferior cooling capacity of the brick condensers, experiments with iron condensers were made at New Almaden. The first ones tried were those of Mr. F. Fiedler, who in 1873 was superintendent of the Hacienda. A figure of the Fiedler condenser has been already given in the paper of M. Rolland* already cited in my former paper.

The Fiedler condenser was a large cast-iron box, 10 feet 7 inches long by 5 feet 6 inches wide and 5 feet 3 inches high, made of iron ½ inch thick. The bottom of the condenser sloped in both directions from the axis as in the brick condensers, and discharged the quicksilver by means of goose-necks. The fumes were introduced by an iron pipe at one end and discharged through another at the opposite end. Three boxes containing water were placed across the path of the fumes. The two end-boxes projected from the floor of the condenser, and the middle one was suspended from the roof. The result was that the fumes were deflected from a straight path just as in the brick condensers. As a cooling agent the Fiedler condenser was very effective, and it remained in use for two years doing good work. It was, however, finally put aside, as the passages in it were so narrow that they offered considerable resistance to the draft. Besides, the bottom and lower part of the sides were badly eaten by the acid waters.

For some time, experiments in this direction were abandoned. But recently new efforts have been made to make use of this material. The coarse-ore furnaces Nos. 7 and 9 have been provided with condensers similar to those in use at Idria, Austria. As arranged at New Almaden, the fumes pass from the furnaces to separate brick condensers, to deposit any ore-dust they may have carried over. Thence, by means of 3 sheet-iron pipes, 20 feet long and 22 inches interior diameter, inclined at an angle of 20°, they pass into three cast-iron condensers. These condensers may be best described as U-tubes. They consist of two vertical pipes of cast-iron, 22 inches interior diameter, one 10 feet high, the other 13 feet high, which are connected together at the bottom by means of a straight pipe of the same diameter inclined at an angle of 20°. The three U-tubes belonging to each furnace are inclosed in a wooden tank kept full of water by a stream brought to the works from the drainage of the mine.

* *La Métallurgie de Mercure en Californie*, par M. G. Rolland, p. 16.

The connecting pieces of the U-tubes project from either side of the tank. The connecting pipes, as well as the vertical legs of the tubes, are kept clear of soot by means of iron discs. These are moved from time to time by iron rods which pass vapor-tight through man-plates which close the ends of the tubes. The fumes pass from the U-tubes by means of sheet-iron pipes, similar to those by which they entered them, to sedimentation-chambers of brick. In order not to interfere with the action of the soot-discs, the entrance- and exit-pipes are joined on to the sides of the U-tubes.

To protect the iron from the action of acid waters, it is coated inside and out with a thick coating of asphalt and coal-tar. These condensers have given good satisfaction so far at New Almaden, and have been in use for several years at Idria.

"*Water-Backs.*"—Another form of iron condenser introduced by Mr. Randol promises excellent results. This contrivance, locally known as a "water-back," is constructed on the same principle as the surface-condenser of a marine engine. In the two end-walls of a brick condenser, exactly opposite each other, are set cast-iron boxes. These iron boxes are connected by means of iron tubes, and the whole is so arranged that a constant circulation of water may be maintained through them. The cast-iron boxes are made $\frac{3}{4}$ inch thick, and 3 feet 6 inches long by $16\frac{1}{2}$ inches high and $14\frac{1}{2}$ inches deep inside measure. One of them is divided into two equal compartments by means of a horizontal partition while in the other this partition is omitted. Between the lower halves of the boxes run 5 wrought-iron tubes, 4 inches interior diameter and $\frac{1}{4}$ in. thick. These tubes pass water-tight through stuffing-boxes in the backs of the boxes. The glands are tightened from the inside of the box. Six similar tubes connect the upper halves of the boxes. The cold water enters the lower half of the divided box, passes through the five lower pipes to the opposite box and back again by the upper six to the upper side of the divided box whence it is discharged.

The covers which close the fronts of the water boxes when removed give easy access to the interior so that the removal of boiler scale and repairs, when needed, are easily effected.

So long as the water-backs are confined to the hot condensers they do not suffer from the attack of acid. They have the advantage of being comparatively inexpensive and are easily repaired. As cooling appliances they have been exceedingly successful. They are mainly used in the first brick condenser of the system, and act on the fumes as they come hot from the furnace. At No. 1 furnace

(*granzita*), for instance, the result of their introduction has been that the second and third brick condensers now furnish the larger part of the entire quicksilver-product of the furnace. Previous to their use, quicksilver did not appear in any quantity until the fumes had reached the fourth or fifth condenser. In other words the addition of two water-backs to the first condenser has rendered it practically equivalent to three such condensers without them.

These results show the importance of using water-cooled iron, under proper conditions, rather than brick structures for cooling quicksilver fumes. The great difficulty still is the protection of this material from the acid. Asphalt and coal-tar does well enough if put on conscientiously. But the acid finds out any neglect on the part of the workmen, and cleaning the condenser also tends to denude the metal. The Bower-Barff process, if it can be made to work successfully in protecting the iron from the action of the acid liquors, and is not too expensive, would be a great boon to quicksilver producers.

*c. Glass and Wood Condensers.*—In order to replace the heavy masonry walls of the brick condensers, particularly in places where the temperature was low, and acid waters plentiful, a patent was taken out by Messrs. Fiedler and Randol for condensers made of glass and wood.

In their most approved form they are shown in Fig. 7. As seen from the figures the top, bottom, and sides of the condensers are constructed of sashes of ordinary window-glass set without putty. The wood-work of the structure is reduced to a minimum, and no nails or other metallic fastening are used in their construction. The bottoms, placed at a slight angle, are made of glass panes cut V-shaped at the lower ends and set like shingles on a roof; they drain all the condensed metal, water, etc., into a wooden gutter. The general shape of the condenser as seen from the figures is that of a tall square prism ($4\frac{1}{2}$ feet $\times$ $4\frac{1}{2}$ feet $\times$ 25 feet) surmounted by a glass roof. The condensers are connected with each other by flues of glass and wood similarly constructed. These flues join the condensers alternately at their tops and 4 feet above their bottoms. Consequently the fumes pass alternately up one condenser and down the next. In order that the condensed quicksilver globules may be removed as soon as possible from the action of the current, dead spaces are left at the bottom of each condenser into which such metal may settle. The condensers resist the acid waters very well and give very good results so long as they are kept in constant use, but when allowed to

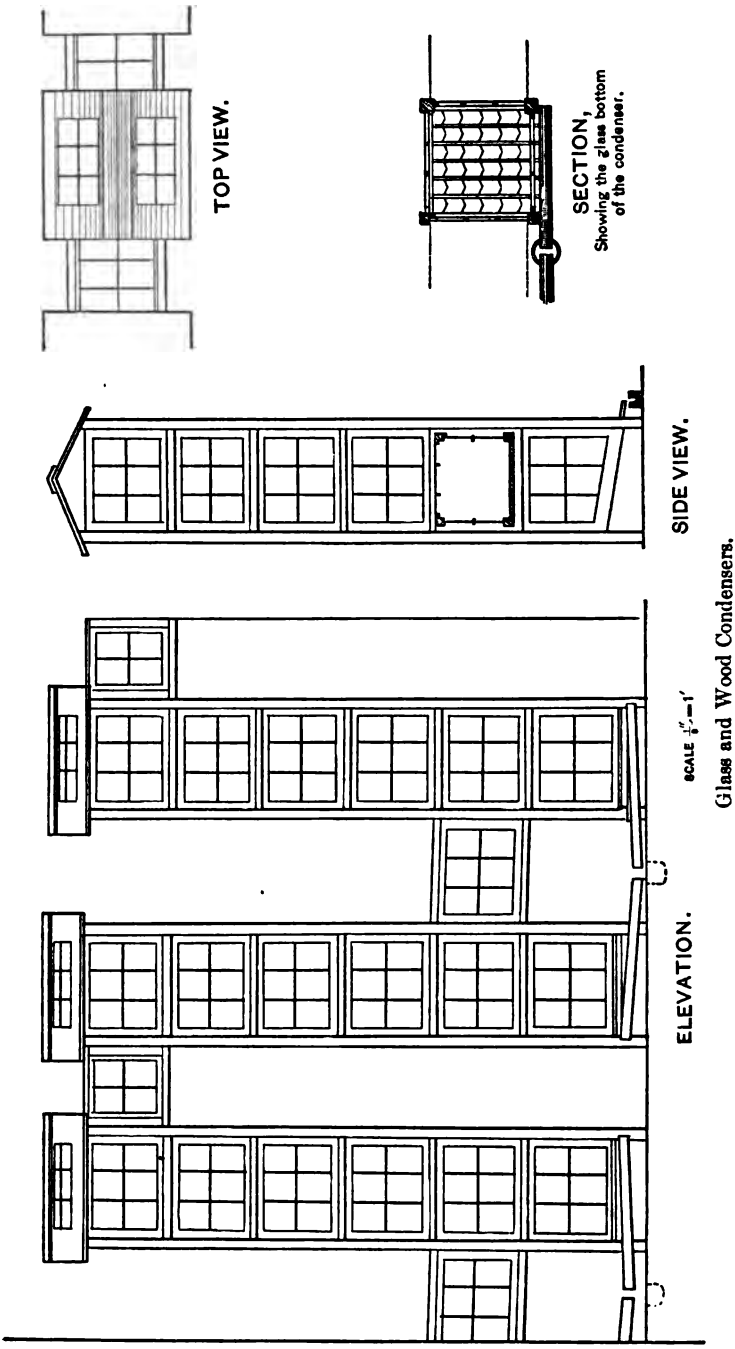



FIG. 7. Glass and Wood Condensers.

remain idle (during furnace-stoppages) they, of course, dry and shrink so that when again used they at first leak air, so as to interfere very much with the draft of the furnace.

This temporary evil might, however, be largely avoided if the wood work they contain were impregnated after exhaustion in vacuo with coal-tar, hot asphaltum or some such substance so as to fill the pores of the wood. Owing to the small amount of wood used in the condensers, this treatment would not add materially to their cost. As the most resistant material to the action of the acid, Puget Sound fir is found to be best.

*d. Friction-Condensers.*—It has long been noticed at New Almaden that the rapidity of condensation depends not only upon the cooling-surface and the sedimentation-volume, but also upon the area of friction- or adhesion-surface to which the fumes are exposed. This has been found to be true, even when the additional surface did not act at the same time as a cooling-surface. The utility of eddies and cross-currents in the fumes themselves has also been well recognized.

Various devices have been applied to utilize these principles. Thus in the wood and glass, as well as the brick condensers, wooden gratings, shelves, partitions, etc., have been used with more or less success.

Among these devices deserves to be mentioned the so-called "revolving screen." These contrivances are considered so successful that a new form of brick condenser has been built to contain them. These condensers are now arranged to receive the fumes from 7 and 9 furnaces as they have passed through the U-condensers. The new brick condensers are tall rectangular prisms 13 feet 1 inch × 10 feet 3 inches × 30 feet high, outside measure. Instead of being provided with brick partitions they contain three "revolving screens" placed one above the other.

These revolving screens have a heavy wooden axle which passes through bearings in the condenser walls, so that they may be set at any angle from the outside. They are not, however, intended to be kept in motion. Fastened to this axis is a damper-blade of heavy planks. When the damper is placed horizontally it obstructs the entire passage across the condenser. When the three dampers are all vertical the condenser is divided into two compartments, and by varying the angles any number of directions may be given to the current of fumes. In addition to the damper-blades the axle carries wooden arms, set like the teeth of a comb, but distributed so as to

form the elements of a helicoidal surface. It is evident that these arms, while they offer little obstruction to the draft, cause a multitude of changes of direction and vortex-motions, while they also offer considerable friction-surface to the fumes. The revolving screens as well as the interior of the condenser are heavily coated with asphaltum.

*e. Flues, Towers, and Chimneys.*—After leaving the last condenser of each furnace-system, the fumes are conducted by wooden flues to brick towers, containing in some cases "auxiliary fire-places." Thence they pass, by means of brick flues, built on the hillside and partly submerged in the earth, to the chimneys on the side-hills. Each of these contrivances merits a passing notice.

The wooden flues now used have been perfected, after many attempts to get one that would remain tight under the alternate conditions of use and disuse. The form now used originated at New Almaden, and is covered by Baker's United States Patent, No. 235,063. It seems to be very successful.

It is a nearly rectangular wooden tube. The sides, however, instead of being planes, are slightly cylindrical. In a flue 36 inches $\times$ 36 inches, the curvature of the sides is 2 inches from the chord of the arc at the middle of each side. The flue itself is made of two thicknesses of one inch tongued and grooved redwood boards, laid so as to break joints, and usually with a layer of asphaltum paper or felting between the layers.

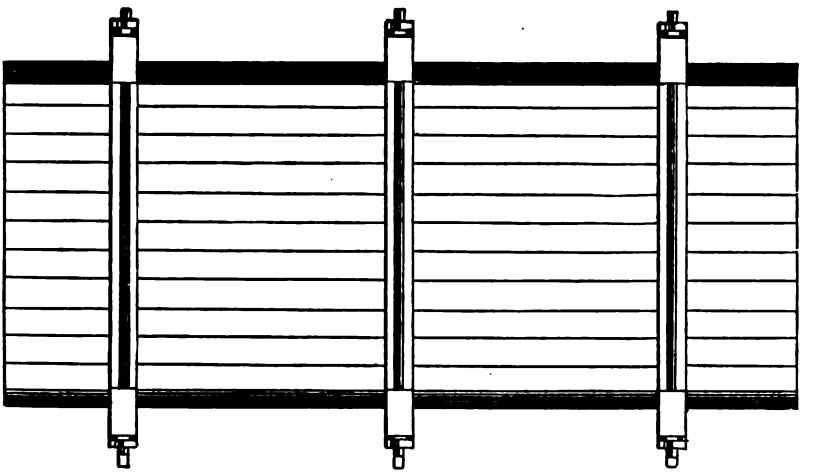
At intervals of 6 feet are placed square frames of 3 $\times$ 6-inch stuff, curved on the inside to grasp the sides of the flue and arranged with wooden wedges for the side-frames and two tie-bolts for the top and bottom frames, so that the whole flue may be tightened by these means like a barrel. These flues may be evidently built tight without the use of a nail, and, except the two tie-bolts which are exterior to the flue itself, without any metallic fastening whatever. They are wedged up close when they are dry, and when the moist fumes enter they swell perfectly tight. They are usually payed inside with a coat of hot asphaltum and coal-tar and are painted outside.

Figs. 8 and 9 show the Baker flue, except that, as now built, the corner-timbers are left out and the corners are made by the boards themselves, which are arranged to break joints.

The auxiliary fire-places are placed in the towers at the bottom of the side-hill flues to heat them so as to increase the draft through condensers when the weather requires it. Fires are mostly needed

in the hot summer months, but may be required at any time during the year.

FIG. 8.

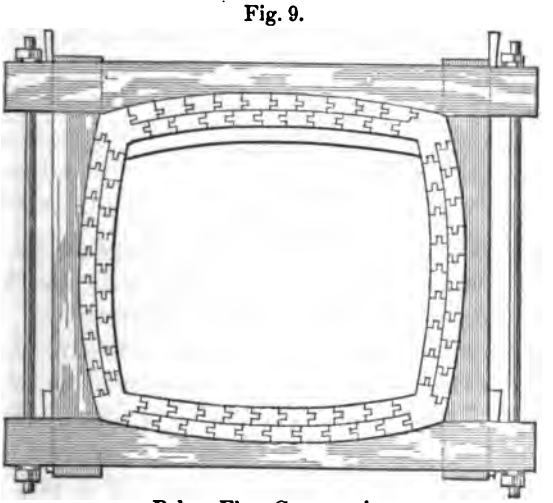


Baker Flue, Side-elevation.

Scale ¼ in. = 1 ft.

The fumes from furnaces 1 and 2 are led into the same tower with auxiliary fire-places, thence through a cylindrical side-hill brick flue, 3

Fig. 9.



Baker Flue, Cross-section.

Scale ¼ in. = 1 ft.

feet 4 inches interior diameter, to the chimney, 3 feet 4 inches square inside. The side-hill flue has a total length of 131 feet, and climbs the hillside, in which it is partly buried.

The brick chimney connected with this flue rises to a height of 20 feet above the flue. The top of the chimney is 61.3 feet above the top of the furnaces, and 100.6 feet above the floor of the works. The total distance from the auxiliary fire-place to the top of the chimney is 151 feet.

Furnaces 7 and 9 also discharge their fumes into a common tower containing an auxiliary fire-place. Thence they pass by a cylindrical brick flue, 4 feet interior diameter, for a distance of 410 feet up the side-hill to a brick chimney which it enters at a height of 233 feet above the floor of the works, or 202 feet above the charging-floor of the furnaces. The chimney is 5 feet square at the base and 4 feet at top, inside measure, and is 60 feet high.

Furnaces 3, 6, and 8 discharge their fumes, each from the condensing system of its furnace, by means of wooden flues 117 feet long, into a brick tower, where they are all united. A Guibal fan, to be mentioned later, here replaces the auxiliary fire-place. From the brick tower the fumes pass by means of a cylindrical brick side-hill flue, 5 feet interior diameter, a distance of 650 feet, to the foot of the side-hill chimney belonging to these furnaces. This latter is 5 feet square inside at the base and 4 feet square at the top. It is at the base 305 feet above the furnace, and at the top 385 feet above the floor of the works. The total distance passed by the fumes after leaving the condensers of Nos. 3, 6, and 8 furnaces is therefore:

| | |
|---|---|
| Wooden flues, . . . . . | 117 feet. |
| Brick flues, . . . . . | 650 " |
| Brick chimney, . . . . . | 80 " |
| In all, . . . . . | 847 feet. |

The Guibal fan, used instead of the auxiliary fire-place at these furnaces, is 8 feet in diameter by 27 inches wide, and is run at a speed of 60 to 70 revolutions by a small Knight wheel. The water for this purpose comes from the mine and is afterwards used for condensation. The fan gives very satisfactory results, the only expenses being repairs. The arms of the fan, being of metal, suffer from the fumes; but as this is the only part exposed, this expense is not great. The advantage of the fan is not only the saving of fuel that would be otherwise used, but that the side-hill flue formerly heated by the fire-place may now be properly considered as part of the condensing system. As above shown, this is no inconsiderable addition. The effort is making to introduce a similar change in the other systems.

## II. Analysis of Condensing-Systems.

As already intimated, each furnace has its own condensing-system, which lies between the furnace and the point where the fumes enter the side-hill flues. As now arranged, no two of these systems are arranged exactly alike. This is partly the result of numerous experiments which have been made from time to time for the introduction of improvements, but is mainly owing to the practical necessity of keeping up the output of quicksilver. All changes have been made without stopping the works, which have been in continuous operation ever since the mine came into possession of the company in 1863.

Hence, as the particular arrangement of each condensing-system has largely been a matter of necessity and not of choice, only one has been selected as an example for analysis, and the rest have been very briefly described.

The condensing-system of No. 1 furnace is shown in Table I. It will be understood that the fumes pass from the furnace by means of the two iron pipes shown in Plates IV. and V. of the former paper, directly into the first of the series of six brick condensers. Four of these condensers have two compartments, the rest but one. The first of the system, a double one, contains the two water-backs. The condensers stand side by side with a 4-foot air-space between, and are connected by the earthenware and iron pipes mentioned in the table. The common height of these condensers is 24 feet, 9 inches above their discharge-openings which are 2 feet above the floor of the works. The width of the condensers varies from 6 to 11 feet, according as they are single or double. Two of the double condensers contain a pair of the revolving screens, one in each compartment. The whole set of brick condensers is under-drained by an arched passage which leads any quicksilver that might be otherwise lost back to the weighing room.

From the brick condensers the fumes pass by means of a wooden flue to the wood and glass condensers, 10 in number, and thence, by means of wooden flues and an intermediate brick tower, to the towers with auxiliary fire-place.

Most of the quicksilver is deposited in the brick condensers; acid water is the chief product of the glass ones, although a little quicksilver is caught by them.

In calculating the cooling-areas and interior volumes of the various elements exact measurements were made wherever possible, but in some cases estimates had to be made, as the interiors were of course

## TABLE I.

*Condensing System of No. 1 Furnace.*

| Material of Condenser. | Number. | Thickness of Walls. | Path of Vapors. | Interior Volume. Cubic feet. | Cooling area. Square feet. | $\frac{A}{V}$ | Remarks. |
|---|---|---|---|---|---|---|---|
| Brick condensers, . . . | 6 { 4 double. 2 single. | mostly 9 in., 2 end wall 13 in. | | 16,664 | 8,297 | 0.5 | Volume of water-back and furnace air-pipe deducted from that of condensers. |
| Iron water-backs, . . . | 2 | ½ in. | | [44 not to be added in] | 467 | 10.6 | Exterior volume not to be included in vol. of condensers. |
| Earthen air-pipe to fur'e, | 1 | 1 in. | 250* | [89 not to be added in] | 212 | 2.4 | |
| Iron connecting pipes, . | 12 | ⅛ in. | | 488 | 863 | 1.8 | Exterior surface of all *iron* vessels taken as cooling surface, 2 to 3 ft. diam., 6 to 8 ft. long. |
| Earthenware pipes, . . | 13 | 1 in. | | 97 | 323 | 3.3 | 14 to 16 in. int. diam., 6 to 8 ft. long |
| Wood & glass condensers, | 10 | ⅛ in. gl. | 140 | 4,658 | 4,300 | 0.92 | 4½ x 4½ ft. |
| Wood and glass flues, . | 5 | ⅛ in. gl. | 26 | 372 | 400 | 1.07 | 4½ x 3½ and 4 x 4½ ft. |
| Wooden flues, . . . . | 7 | 2 in. | 90 | 978 | 1,210 | 1.24 | |
| Brick towers, . . . . | 1½ | 9 in., 13 in. | 30 | 2 500 | 1,500 | 0.6 | Last tower half used by No. 2 fur. |
| Brick flue, . . . . . | ⅔ | 4½ in. | 131 | 762 | 914 | 1.2 | 3 ft. 4 in. diam. round; ⅛ used by No. 2 furnace. |
| Brick chimney, . . . | ⅔ | 3 ft. to 13 in. | 20† | 148 | 167 | 1.12 | 3 ft. 4 in. sq. inside. ⅛ used by No. 2 furnace. |
| Totals, . . . . | | | 687* | 26,667 | 18,653 | | |
| Average, . . . . | | | | | | 0.69 | |

* There are several possible paths for vapors in brick condensers. On account of this and the vortices resulting from the many angles and turns in the system, it is probable that the actual path of the fumes is nearly 1000 feet from the furnace to the top of the chimney.

† Height of chimney-top above floor of works 100.6 feet; above furnace top, 61.3 feet.

inaccessible. The column headed $\frac{A}{V}$ is given to show the ratio between the interior volume and cooling-area in the various elements of the system. Evidently the brick condensers make the poorest showing in this respect and the iron water-backs the best, the latter ratio being twenty-one times the first. Besides, the better conducting power of the iron and the heat-absorbing capacity of the water render them powerful adjuncts to the brick condensers. The earthen-ware and iron pipes make a good showing. Their thinness also helps. The glass and wood condensers, particularly when we regard the thinness of their walls, make a good showing also.

The shortest possible path of the fumes is estimated at 690 feet. But owing to the numerous pipes which connect the brick condensers there are several possible paths for the fumes, and as remarked in the table the actual path of the fumes is probably nearer 1000 feet.

Regarding the systems used with the other furnaces, nothing further need be said than to append Table II. which shows the arrangement now in force.

TABLE II.

| FURNACES. | Granzita, No. 2. | Tierra, No. 3. | Tierra, No. 8. | Granza, No. 7. | Granza, No. 9. | Terrero, No. 6. |
|---|---|---|---|---|---|---|
| Brick condensers* | 11 | 9‡ | 4‖ | 4½ | 3½ | 6 |
| " necks to same | 4 | 4 | ..... | ..... | ..... | 1 |
| " towers | 2 | 2 | 1 | ¼ | ¼ | 1 |
| " flues | ⅓† | ⅓ | ⅓ | ⅓ | ⅓ | ⅓ |
| " chimneys (last) | ⅓ | ⅓ | ⅓ | ⅓ | ⅓ | ⅓ |
| Iron pipes (air-cooled) | 9 | 6 | 2 | 9 | 7 | 12 |
| " (water-cooled) | ..... | ..... | ..... | 3 lines. | 3 lines. | ..... |
| Iron water-backs (sets) | 2 | ..... | 2 | 1 | ..... | 2 |
| Earthen-ware pipe (air-cooled) | 23 | 20 | 6 | 35 | ..... | 16¶ |
| " " (water-cooled) | ..... | ..... | 6 | ..... | ..... | ..... |
| Glass and wood condensers, with necks of same. | 14 | ..... | ..... | ..... | ..... | ..... |
| Wooden flues | 1 | 2 | 1 | ½ | ½ | 1 |
| Friction-screens and revolving screens | Nearly all contain some one or other of these contrivances. | | | | | |

* Some of the brick condensers are single, some double; and one contains three compartments Most of these latter, however, are attached to intermittent furnace No. 6.

† Used in common with No. 1 furnace.

‡ One of these is a combined condenser and ore-drier.

⁋ Furnaces Nos. 3, 6 and 8 use the same side-hill flue and chimney.

‖ These are topped with iron and are used to dry ore.

¶ In addition, the brick condensers of Nos. 6 and 8 furnaces are perforated by numerous earthen-ware pipes, through which air circulates, so as to increase their cooling capacity.

## III. Temperature of Condensers.

Isolated temperature-determinations are of no value. Some determinations were made in a systematic manner by Mr. J. R. Smedberg, in February, 1880, with No. 9 (*Granza*) furnace and its condensing-system. These are given in Tables III. and IV.

The furnace-temperatures were determined by calorimetric methods, an iron ingot being used; the condenser-temperatures were taken with a mercurial thermometer.

### Table III.

*Furnace No. 9. (See Plate III., previous paper.)*

| | ° C. | ° F. |
|---|---|---|
| 1. Lowest peep-hole (above fire-place), . . . . . | 823° | 1513° |
| 2. Next higher, . . . . . | 946° | 1735° |
| 3. " " . . . . . | 878° | 1612° |
| 4. Topmost peep-hole (near furnace throat), . . . . . | 372° | 701° |

The second peep-hole from the bottom shows the highest temperature, probably owing to the coke, mixed with the ore, which has got well on fire at this point. The temperature rapidly falls between the two upper peep-holes to only 12° C. above the boiling point of quicksilver, owing to the heat-work done on the raw ore, viz., evaporation of hygroscopic and combined water, decomposition of dolomites, etc. Hence the fumes escape, as they should, just above the boiling point of the metal.

### Table IV.

| Point Taken. | ° F. | ° C. | Fall ° C. |
|---|---|---|---|
| Topmost peep-hole of furnace, . . . . . | 701 | 371.7 | . . . . |
| End of down-take from furnace. Entrance to 1st brick condenser, . . . . . | 375 | 190.6 | 181.1 |
| End of 2d brick condenser, . . . . . | 100 | 37.8 | 152.8 |
| End of 1st glass and wood condenser, . . . . . | 78 | 25.6 | 12.2 |
| " 2d " " " . . . . . | 64 | 17.8 | 7.8 |
| " 3d " " " . . . . . | 60 | 15.6 | 2.2 |
| " 4th " " " . . . . . | 58 | 14.4 | 1.2 |
| " 5th " " " . . . . . | 58 | 14.4 | 0 |
| " 6th " " " . . . . . | 57 | 13.9 | 0.5 |
| " wooden flue. Entrance to side-hill flue, . | 56 | 13.3 | 0.6 |
| Temperature outside air, February 25th, 1880, . | 55 | 12.8 | |

It will be remembered that the fumes from No. 9 furnace are collected by an iron down-take which surrounds its head; this acts also as a part of the condensing system, and is indeed here quite effective. In the determinations given in Table IV. the points taken are in the exit flues of each member of the condensing series, and the temperatures given are those of the fumes as they leave that member.

It must be remarked that the condensation-system then used differed from the one now in use and given in Table II. The first two brick condensers are the same, but the glass and wood condensers have been replaced by other contrivances. The glass and wood condensers then used had greater volume, but less cooling area than those now used. Still the cooling effect of the system leaves little to be desired; for the fumes escape at a temperature only about 0.5° C. or 1° F. above that of the outside air.

The greatest fall of temperature takes place in the "down-take," and is 181° C., and next in the two brick condensers, where it is reduced 153.8° C. more. The fumes have been thus reduced to a temperature of 37.8° C., and are, as we shall see later, already cooled below the "dew-point," and moisture already appears. After that, as the fumes come nearer to the temperature of the air, the temperature falls very slowly in spite of the thinness of the walls of the glass condensers. A further addition of condensers would probably not have reduced the temperature below this limit unless resort were had to artificial cooling.

## IV. Product of Condensers.

The product of the condensers is not entirely quicksilver. There is always some fine ore-dust carried into the condensers. This is, however, mainly confined to the first condenser of the series. In this condenser, I also found on one occasion some white anhydrous sulphate of mercury, but this is a rarity. The interior of all the condensers, walls, roofs, and floors are covered with a black soot. This is composed mainly of unburned carbon and hydrocarbons of tarry empyreumatic nature. These ingredients come mainly from the imperfect combustion of the fuel, but also in some part from the tarry matter in the ore itself. The former cause might be removed by careful firing; but the latter, as well as that coming from charging raw coal, as is sometimes done with the ore, could hardly be avoided.

The soot contains, mechanically entangled, large quantities of

metallic quicksilver, most of which can be removed by mechanical treatment. In addition a certain amount remains in the residues from this operation which cannot be removed in this manner.

The New Almaden soot has not been analyzed, but its composition is probably similar to that of the Idria works. According to analyses of the latter by Bergrath Patera and others,* the Idria soot contains from 15 to 50 per cent., or an average of 25 per cent. quicksilver. In some cases as much quicksilver as 41 per cent. of the weight of the soot could be extracted by mechanical means, leaving 10 per cent. that could not be extracted in this way, 9 per cent. of which exists as sulphate or sulphide. Most of the analyses, however, show only $\frac{1}{3}$ to $\frac{1}{12}$, or even less, of the quicksilver to be present in the metallic state.

The New Almaden soot contains more or less scrapings from the walls of the condensers, and in the colder condensers, where the moisture has had time to condense and the sulphurous acid to oxidize, the soot is impregnated with dilute sulphuric acid. The hot condensers next the furnaces furnish mainly dry quicksilver and soot mixed with ore-dust. Farther on they furnish quicksilver, acid waters, and damp soot, and the last condensers furnish dribbling streams of inky acid waters, holding various sulphates in solution, colored by the soot and carrying small amounts of finely divided quicksilver. The soot of these chambers is, of course, a black mud. Finally, the side-hill flues, deprived of the larger part of condensable moisture and quicksilver, furnish nearly dry soot which rarely shows to the eye any free quicksilver.

In order to separate the quicksilver from the acid waters, they are run very slowly through settling boxes of heavy wood. These have vertical partitions which force the stream to take a circuitous path through a filter of charcoal or coke. The metal which settles in these boxes flows off through a goose-neck at the bottom in the dry state to the weighing-room, no further purification being necessary. The filters are from time to time charged back into the furnace with the ore and are replaced by fresh coke or charcoal.

The soot which collects on the walls gradually accumulates and finally falls on the floors of the condensers. This is then removed from time to time through the manholes at the ends of the condensers, with long hoes, by a special set of workmen, the "soot-men."

---

* *Die K. K. Quecksilberwerk zu Idria in Krain.* Translated by S. B. Christy. Published by J. B. Randol, San Francisco, 1884. See p. 52 of translation.

The hoes are made either of wood, or better, of square pieces of thick rubber cloth held between iron plates at the center, so that the floors may be abraded as little as possible by the frequent cleanings. The cleaning of the floors of the condensers goes on during the working of the furnaces. If the draft of the flues is in proper working order, there is no danger to the men, who open but one manhole at a time, and are, consequently, protected from the fumes by the strong inward draft. The doors of each condenser are luted up before the next is opened.

At the end of a campaign, the walls are first washed down with a hose, and then the men enter the condensers and remove the soot from the walls and roofs, as well as from the floors of the condensers. The metal resulting from these clean-ups is usually added to the following run. As a consequence, no quicksilver is produced when the furnace again starts up, until the walls of the condensers are again coated with soot. This may be seen from the furnace records for the year 1882, given in the previous paper; notably in the case of No. 8 furnace, where no quicksilver was obtained from the condensers for *seven* days after starting the furnace.

Hence it is extremely difficult, if not impossible, to determine with exactness the yield of any particular lot of ore, as the product will depend on the relative care with which the clean-ups are made before and after each run. The area to be cleaned is very great; it is a very disagreeable task to the men who have to enter the condensers; and it is not easy to superintend their work, which is, therefore, not likely to be done very exactly in any case. Hence results depending on clean-ups are not very certain. If, on the other hand, no clean-ups at all were made, the same difficulty would exist; for a greater or less, but always unknown, amount of metal would be left adhering to the walls.

Of course these facts show the absurdity of claims sometimes made that experiment shows that certain quicksilver-furnaces save 99.9 per cent. of the quicksilver in the ore. Even supposing the sampling and assaying to have been properly done, the experiment could not positively show such a yield.

In practice, however, what is left over in the condensers in one run is saved in the next, and so, in showing the yield of the furnace runs for any period, it is evidently a reasonably fair exhibit to count in the clean-ups of the previous run (when made on nearly the same grade of ore and for the same time) just as is done in the ordinary routine of the works.

## V. Treatment of Soot.

Numerous experiments and frequent improvements have been made in this direction, as well as in other branches of the treatment of the ore. The method at present used is to spread the soot on an inclined floor of cement, where it is mixed with dry wood-ashes to brighten the quicksilver. It is then rabbled with wooden hoes till all the metal that can be extracted in this manner has been removed, and the residues are charged back again with the ore into the furnace from which they came.

Experiments have been made, in which the rabbling treatment was supplemented by stirring the residues in a hot lye of wood-ashes, both by hand in iron vats, and by power in an ordinary amalgamating-pan; but the present method is considered not only less expensive and troublesome but more satisfactory.

No record is kept of the total weight of soot produced by the furnaces. In all cases the metal extracted from the soot of each furnace goes in with the yield of that furnace, but a separate record of the amount so produced is not always kept.

The results, as far as they could be ascertained for the year 1882, and shown by the "Summary of Furnace Records" for that year, are as follows:

Table V.

| | From Condensers. | From Soot. | Total. | From Soot. |
|---|---|---|---|---|
| 1 flask = 76.5 lbs. Ad. | Flasks. | Flasks. | Flasks. | Per cent. |
| 2 Granzita and 2 Tierra furnaces, . | 10,165 | 604 | 10,769 | 5.61 |
| 2 Granza furnaces, . . . . . | 11,675 | 494 | 12,169 | 4.06 |
| 1 Intermittent furnace, . . . . . | 5,108 | 24* | 5,132 | 0.468 |
| Total, . . . . . | 26,948 | 1,122 | 28,070 | 3.997 |

In other words, about 4 or 5 per cent. of the entire quicksilver-product of New Almaden is extracted by mechanical means from the soot. At Idria, Austria, the quicksilver obtained from the soot is over 16 per cent. of the total yield, or more than three times that of New Almaden. Consequently the treatment of soot at the latter place is not of such moment as it is at Idria.

* The returns from this furnace were incompletely separated.

At New Almaden the soot is removed from the condensers and treated at a very small expense. Thus, in 1882, the total expense was $2,509.85, or $2.237 per flask extracted from it. The additional expense per ton of ore treated, has been shown (in the previous paper) to be only $0.066.

The workmen who perform this work suffer occasionally from salivation if they are careless about the proper use of masks, bathing, etc., but as they are paid more than the ordinary workmen, there is no lack of applicants.

Although the above figures show only a small margin of possible profit by improved methods of treating the soot, the use of an hydraulic press to replace the manual labor in stirring, is being considered. If this device proves successful, more quicksilver than is now obtained by hand will be directly produced, and the residues will come from the press in hard dry cakes ready to go to the furnace for subsequent treatment. As a sufficient head of water already exists to produce the necessary pressure, the expense of cleaning the condensers will be almost the only one left, and the total cost may thus be reduced to a very small figure.

## VI. Losses of Treatment.

*a. Nature of the Losses.*—There is perhaps no subject on which greater differences of opinion exist, than upon the losses which occur in roasting quicksilver-ores. These losses have been variously estimated by different persons at all the way from 50 per cent. by pessimistic critics to 0.1 per cent. by optimistic inventors.

Unfortunately for the purpose of this inquiry, it is not customary at New Almaden, or at any of the quicksilver-mines of California, to take careful and systematic samples for assay, as is done at Idria, Austria. This is largely due to the fact that the margin of profit in treating these ores is not great, and the wages of skilled labor are very much higher in California than they are in Europe. One systematic test made at New Almaden will be made use of later on.

Furthermore, I have been unable to find, in the whole range of quicksilver-literature, any adequate determination of what must be the inferior limit of the losses on the plan of treatment selected. In other words, there is at present no criterion by which we may judge as to whether a given condensing-system is doing the best that can

be expected of it, or by which we can even approximately estimate the relative value of different systems.

It is the purpose of the present inquiry to find that criterion, and in the absence of extensive and systematic tests, to judge, as near as may be, not only of the work now done at New Almaden, but also to see in what direction efforts should be made to improve upon the results now obtained in practice.

In the first place we may classify the sources of loss as follows:

(1.) Furnace-loss: loss in residues from roasting-furnaces.

(2.) Condenser-loss: loss as vapor or liquid in condenser-structures.

(3.) Chimney-loss: loss of quicksilver in the escaping gases. This latter may be either:

(*a.*) Quicksilver in the form of vapor, or

(*b.*) Condensed globules, or quicksilver-mist.

Regarding the furnace-loss: There is no doubt that the amount of this loss is easily reducible in the modern furnaces, when skilfully used, to a quantity which may be neglected. This is a matter so easily arranged, that there is no excuse whatever for any loss in this direction. If the fumes are discharged at the top of the furnace, at a temperature above the boiling-point of quicksilver, and the ore is kept long enough in the furnace to discharge all the quicksilver from it, and the draft is maintained so that there is no back-pressure, and the furnace is properly constructed with iron jacket and with iron plates in the foundations, this source of loss becomes insignificant. Still the tailings will always warrant careful examination, as a check on careless workmen.

All the above conditions are fulfilled in the most admirable manner at New Almaden. A series of careful and systematic tests made at New Almaden, in 1880, by Mr. Charles Butters, showed that, when properly managed, the furnaces left only traces of quicksilver in the roasted ore. The method of analysis used was one devised by Mr. Reese of Falkenau and Reese, of San Francisco, and merits special notice from its simplicity and accuracy. The results showed traces mostly unweighable, except in cases of carelessness on the part of the workmen. Five-hundredths of one per cent. was the maximum loss when the furnaces were running properly. Traces only were in most cases reported.

Regarding the condenser-loss, almost the same may be said. In view of the great care to maintain an inward draft in the condensers, the vapor-loss may here be regarded as zero. The great

pains now taken in furnace-construction, render the loss of liquid quicksilver a minimum. Of course the masonry is sure to be somewhat permeated by quicksilver. This, however, is rather unproductive capital than loss, since it is always regained by roasting with the ore the débris of old condensers, when they are pulled down.

The chief and unavoidable loss is therefore what we have called the chimney-loss. This is two-fold, the vapor-loss and the quicksilver-mist loss. The gases which escape from the furnace must of course be saturated with quicksilver-vapor at the temperature of escape. Regnault's experiments show that quicksilver is volatile at all temperatures within range of experiment. Even frozen quicksilver loses weight at a temperature of —39° C. As the volume of gas which escapes from a quicksilver-furnace is enormous, this loss may easily become very great. It is not difficult to calculate what this loss must necessarily be under given circumstances.

This is not, however, the case with the second cause of loss. Much has yet to be learned regarding the nature of fogs and mists, even of water. We might calculate at least the limiting diameter of a quicksilver globule that would just float in an ascending current of gas of given velocity and density. But no reliable means are yet known for calculating the number of such globules that would be carried off by such a current. Moreover, it is still an open question, whether mists are composed of liquid globules or hollow vesicles. Experiment alone can determine the importance of this source of loss.

Regarding these losses, it would seem *a priori* that we might hope to remove the condensed globules or vesicles by mechanical means, friction-surfaces, filtration, etc. Regarding the first cause, however, under given conditions as to volume of escaping gases, temperature, etc., this *loss is unavoidable, and cannot be prevented by any mechanical contrivance.* This, then, may be selected as the *minimum possible loss with any given system.* Of course the time is still far distant when this degree of perfection can be hoped for.

Let us examine the nature of this loss more carefully. It is evidently of first importance to know the nature, weight, and volume of the gases which escape from the furnaces. This may be determined most simply by direct measurement of the volume and analysis of the escaping gases. But single determinations would scarcely be reliable, and hence the average of a number extending over the whole year, should be taken. At New Almaden, some isolated determinations of the velocity of escaping fumes have been made, but with exception of those of Mr. Smed-

burg's experiments on No. 9 furnace, already cited, none of these can be made use of here.

*b. Composition, Weight, and Volume of Dry Furnace Gases.*—I have decided that the fairest average result can be obtained by calculation. Knowing the weight and kind of fuel used, and assuming (as is customary) that twice the theoretic amount of air is required for complete combustion of the solid fuels used, we can easily calculate the weight and consequent volume of the resulting products of combustion. The above assumption is borne out by Mr. Smedburg's experiments with No. 9 furnace, where he found the actual volume of the air admitted to the furnace to be 36 per cent. more than double the theoretic amount. In consequence of these experiments, the grate-surface of the furnace was reduced so as to bring the quantity of air down to double the theoretic amount.

In order to make the result apply to the entire reduction-works, I have taken what may be called the "average furnace-day," as a basis. In the "Summary of All the Furnace Records" and in the other tables for 1882, given in the previous paper, we have the total number of days run of all the furnaces, the weight of ore and fuel burned, and hence all the data for such a calculation.

For all the furnaces there were in 1882 together 1811.75 working days. There were treated in this time 36,073.60 tons ore, giving an actual yield of 2.976 per cent. The total amount of fuel used was as follows:

| | Pounds. |
|---|---|
| Wood, 2234.624 cords @ 2780 lbs., | 6,212,254.72 |
| Coke, 80,736 lbs. / Charcoal, 346,388 lbs. | 427,124.00 |
| Coal, bituminous, | 395,860.00 |

On account of similarity of composition the charcoal and coke have been taken together, an average composition being assumed later on.

Dividing these weights by 1811.75 and, for convenience in subsequent calculations, converting the resulting weights into kilogrammes @ 2.2046 lbs., we have as the fuel-consumption per "average furnace-day" of 24 hours at New Almaden—

| | | Kilogrammes. |
|---|---|---|
| Per furnace-day | Wood, | 1,555.320 |
| | Coal, | 99.109 |
| | Charcoal and coke, | 106.936 |
| Ore treated per furnace-day, | | 18,063.060 |

The average composition of the wood (air-dried), the bituminous coal, and the average of charcoal and coke, and of the ore are given in Table VI. This table contains also the products of combustion, and the volume at 0° C. and 760 mm. pressure of the *dry* gaseous products of combustion, resulting from the combustion of 1 kilogramme of each of the above fuels with single and double theoretic weights of air.

Table VI. gives also the dry gaseous products produced by roasting 1 kg. of the ore. In explanation of these figures, it may be stated that experiments made by Mr. Smedburg with the ore of Nos. 7 and 9 furnaces (rich granza), with a quicksilver-content of 7 per cent., showed that the fixed residues after roasting amounted to 67.55 per cent. of the weight of the original ore. The average content of *all* the ore treated in 1882 being only 3 per cent., we have taken as a fair estimate of the fixed matter 75 per cent. Two per cent. for the sulphur combined with the quicksilver and in pyrite, etc., is a liberal allowance, probably a little high. This would leave 20 per cent. for the chemically combined and hygroscopic water in the serpentine and "vein-matter," and for the carbonic acid in the dolomitic ingredients of the vein-matter. In the absence of more definite information, the water and carbonic acid are assumed to exist in equal quantities, viz. 10 per cent. each. Hence the assumed composition will be as follows:

| | |
|---|---|
| Fixed matter, | 75 per cent. |
| S, | 2 " |
| Hg, | 3 " |
| $H_2O$ (comb. and hygr.), | 10 " |
| $CO_2$, | 10 " |
| | 100 per cent. |

It may be objected that a great deal is assumed. But it is believed that all the assumptions are reasonable ones, and as will be seen later, even supposing an error of a few per cent. to be made one way or the other regarding these compositions, such errors can not essentially modify the conclusions drawn.

Table VI. also contains the weight of 1 cubic meter at 0° and 760 mm. of each of the dry gaseous products of combustion, which were used in calculating it. These values are taken from Bunsen's *Gasometrische Methoden*, 2d Auf., pp. 380–82.

## TABLE VI.

*Composition and Volume of Dry Gases Produced by 1 kg. of Fuels and Ore at 0° C. and 760 mm. Hg.*

| Substance. (Weight taken in all cases, 1 kilogramme)..... | Composition. | | | | Carbon. | | | Free Hydrogen. | | Req. Oxygen. | | Nitrogen with Req. Oxygen. | | Total Theoretic Air. | | Total Steam. | Dry Products of Combustion. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Produces. | | | | | | | | | | | Theoretic air. | Double theoretic air. |
| | Ash. | C. | Free H. | Comb. and Hygr. $H_2O$. | Requires O = 16a/6 | $CO_2$ = 22a/6 | $CO_2$ 0°C. and 760 mm. | Requires O = 8b. | Produces $H_2O$ = 9b. | d + g. | 0°C. and 760 mm. | N = 3.314 O | 0° C. 760 mm. | 1 + l. | k + m 0° C. 760 mm. | c + h. | f + m 0°C. 760 mm. | f+m+o 0°C. 760 mm. |
| | kg. | kg. | kg. | kg. | kg. | kg. | cu. m. | kg. | kg. | kg. | cu. m. | kg. | cu. m. | kg. | cu. m. | kg. | cu. m. | cu. m. |
| | | a. | b. | c. | d. | e. | f. | g. | h. | i. | k. | l. | m. | n. | o. | p. | q. | r. |
| Wood (air-dried) | 0.01 | 0.40 | ..... | 0.59 | 1.067 | 1.467 | 0.746 | ..... | ..... | 1.067 | 0.746 | 3.536 | 2.814 | 4.603 | 3.560 | 0.590 | 3.560 | 7.120 |
| Bit. coal ..... | 0.05 | 0.69 | 0.03 | 0.23 | 1.840 | 2.530 | 1.287 | 0.240 | 0.270 | 2.080 | 1.421 | 6.893 | 5.486 | 8.973 | 6.887 | 0.500 | 6.773 | 13.660 |
| Av. chcl. & coke | 0.05 | 0.85 | ..... | 0.10 | 2.267 | 3.117 | 1.585 | ..... | ..... | 2.267 | 1.585 | 7.513 | 5.979 | 9.780 | 7.564 | 0.100 | 7.564 | 15.128 |

| | Hg. | S. | $H_2O$. | $CO_2$. | Requires O. | Produces. | | S requires O, total wt. kg. | Produces. | | Total O, cu. m. | N in air, kg. | N in air, cu. m. | Total theoretic air. | | Total steam, kg. | As above, cu. m. | As above, cu. m. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $CO_2$ kg. | $CO_2$ cu. m. | | $SO_2$ kg. | $SO_2$ cu. m. | | | | kg. | cu. m. | | | |
| Ore, [fixed m. 0.75] | 0.03 | 0.02 | 0.10 | 0.10 | 0. | 0.100 | 0.051 | 0.020 | 0.040 | 0.014 | 0.014 | 0.066 | 0.053 | 0.086 | 0.067 | 0.100 | 0.118 | 0.185 |

Air at 0° C., 760 mm.

By volume { O = 20.96 p. ct. N = 79.04 p. ct. } N / O = 3.314 by wt.

By weight { O = 23.18 p. ct. N = 76.82 p. ct. } N / O = 3.771 by vol.

Wts. used in computing above Table (from Bunsen). 1 cu. meter at 0° C. and 760 mm. pressure.

O — 1.4303 kg.

N — 1.2566 kg.

Air — 1.2936 kg.

$CO_2$ — 1.9666 kg.

$SO_2$ — 2.8640 kg.

We are now in a position to calculate the composition of the furnace-gases and their volume. For convenience, we will deal with this volume dry and at 0° C., and make the proper corrections later on. Table VII. thus follows directly from Table VI. and the preceding.

TABLE VII.

*Products of Combustion per Average Furnace-Day.*

| Per 24 hours. | $CO_2$. | $H_2O$. | N. | Excess air. | $SO_2$. | Hg. | Dry products Combustion, Double air. |
|---|---|---|---|---|---|---|---|
| kg. | kg. | kg. | kg. | kg. | kg. | kg. | 0° C. & 760 mm. cu. m. |
| Wood..... 1,555.320. | 2,281.66 | 917.64 | 5,499.61 | 7,159.14 | ..... | ..... | 11,073.90 |
| Coal..... 99.109. | 250.75 | 49.56 | 683.16 | 889.31 | ..... | ..... | 1,353.83 |
| Charcoal and coke. 106.936. | 333.32 | 10.69 | 803.41 | 1,045.84 | ..... | ..... | 1,617.73 |
| | | | | | | 2.976 per ct. yield. | |
| Ore..... 18,063.060. | 1,806.31 | 1,806.31 | 1,192.16 | 1,553.42 | 722.52 | 537.557 | 3,341.67 |
| 19,824.425. | 4,672.04 | 2,784.20 | 8,178.34 | 10,647.71 | 722.52 | 537.557 | 17,387.13 |

Now, as we have seen, the fumes escape from the furnace at a temperature above the boiling-point of quicksilver, and gradually cool down in the condensers. Evidently, as soon as the permanent gases reach their "dew-point" for quicksilver, and not till then, will any quicksilver be condensed. That is, the gases must be saturated with quicksilver-vapor before any will be deposited. The same will be true of the aqueous vapor. As all the cold condensers contain condensed water, it follows that the gases which pass through them must be saturated with aqueous vapor.

Hence, for the temperatures that concern us the gases must be regarded as saturated with aqueous vapor as well as quicksilver vapor. These causes will increase the volume of the dry gases. Let us next consider the amount of this increment.

*c. Volume of Wet Gases.*—We will first determine the increment of volume due to saturation of the dry gas with aqueous vapor at various temperatures:

Let $v_0$ = volume of dry air at temp. $t$ (° C.).
$p_0$ = barometric pressure = $760^{mm}$.
$p$ = tension of saturated aqueous vapor at $t$ (° C.).
$v$ = volume of air saturated with aqueous vapor at temperature $t$ (° C.).

Then,

$$v_0 p_0 = v(p_0 - p)$$

$$v = v_0 \frac{p_0}{p_0 - p} = v_0 \frac{760}{760 - p}.$$

TABLE VIII.

| $t$ (°C.). | $p$ in mm. Hg, Determinations of Magnus. | $v = \frac{p_0}{p_0 - p} \times v_0$. |
|---|---|---|
| 0 | 4.5 | $1.006v_0$ |
| 15 | 12.7 | $1\ 016v_0$ |
| 20 | 17.4 | $1.023r_0$ |
| 40 | 55.0 | $1.078r_0$ |
| 60 | 148.6 | $1.243r_0$ |
| 80 | 353.9 | $1.871v_0$ |
| 100 | 760.0 | $\infty$ |

The tension of the quicksilver vapor will also add somewhat to the volume of the gases; but, as even at 100° C. this tension is only $0.21^{mm}$, the increment due to this cause will be too small to notice here.

This latter increment will also be more than neutralized by the absorption of $SO_2$, $CO_2$, etc., by the condensed water. It would, however, be an absurd refinement to introduce these factors here.

Let us next consider the weight of aqueous vapor required to saturate 1 cubic meter of the dry fumes at various temperatures. Now, as all gases under constant pressure are vacua to each other, the weight of aqueous vapor contained in a cubic meter of any gas saturated with it will be the same as the weight of saturated aqueous vapor contained in a cubic meter free of other gases at the same temperature and pressure. Hence we may use directly the results given by Zeuner, *Grundzüge der Mechanischen Wärmetheorie*, Table 1, b.

This table gives in the last column, headed $u$, the specific volume of aqueous vapor at the temperatures and pressures given. That is, the volume in cubic meters of 1 kilo. of water in the form of saturated vapor under these conditions. Hence the reciprocal of these numbers gives the weight of a cubic meter of aqueous vapor contained either in a vacuum or in any gas under these conditions, when saturated. In Table IX. $v$ is the volume of saturated aqueous vapor furnished by 1 kilo. water, and is taken from Zeuner; $w$ is calculated from this $= \frac{1}{v}$.

TABLE IX.

*Weight of Aqueous Vapor Contained in 1 cu. meter Saturated Gas.*

| Temperature. | Vapor Tension. | $v$. | $w$. |
|---|---|---|---|
| ° C. | mm. | cu. m. | kg. |
| 0° | 4.600 | 210.660 | 0.00475 |
| 15 | 12.699 | 79.346 | 0.01290 |
| 20 | 17.391 | 58.720 | 0.01703 |
| 40 | 54.906 | 19.644 | 0.05091 |
| 60 | 148.786 | 7.6531 | 0.13067 |
| 80 | 354.616 | 3.3789 | 0.29595 |
| 100 | 760.000 | 1.6496 | 0.60621 |

Next let us determine the volume of the furnace-gases at various temperatures, dry and saturated:

TABLE X.

*Volume of Products of Condensation Dry and Saturated with Aqueous Vapor at Different Temperatures.*

| $t$ ° C. | $1 + \alpha t$. | Volume Dry Gases. $v = v_0(1 + \alpha t)$ $p_0 = 760$ mm. | $\frac{p_0}{p_0 - p}$ $p$ = tens. aq. vap. | Vol. Sat. Gases. $v_1 = v \frac{p_0}{p_0 - p}$ |
|---|---|---|---|---|
| 0 | 1.0000 | 17,387 cu. m. | 1.006 | 17,491 cu. m. |
| 15 | 1.0550 | 18,343 " " | 1.016 | 18,637 " " |
| 20 | 1.0733 | 18,661 " " | 1.023 | 19,091 " " |
| 40 | 1.1466 | 19,936 " " | 1.078 | 21,491 " " |
| 60 | 1.2199 | 21,210 " " | 1.243 | 26,365 " " |
| 80 | 1.2932 | 22,485 " " | 1.871 | 42 069 " " |
| 100 | 1.3665 | 23,759 " " | $\infty$ | ..... |

But Table X. cannot be directly used, as the total weight of water produced by the furnace, as given in Table VIII., was only 2784 kg. Hence it follows that the amount of water contained in the gases may be insufficient to saturate them at all temperatures between 0° and 100° C. This temperature may be found close enough for our purpose by the combined law of Gay-Lussac and Mariotte, as follows:

Let $v_0$ = vol. dry gases at 0° C. and $p_0 = 760^{mm}$.

$v$ = vol. gases when just saturated by C = 2784 kgs. water.

$w$ = wt. aqueous vapor in 1 cu. m., at this point.

$p$ = tension aqueous vapor at this point.

$v_1$ = volume saturated steam at $t_1 = 100°$ C.

$w_1$ = wt. 1 cu. m. steam at $t_1 = 100°$ C.

$p_1 = 760^{mm} = p_0$ in this case.

$t$ = required temperature.

$\alpha$ = coefficient of expansion for 1° C. = 0.003665.

Then $$C = v\,w = v_0\,(1+\alpha t)\,\frac{p_0}{p_0 - p} \times w_1\,\frac{1+\alpha t_1}{1+\alpha t}\,\frac{p}{p_1}$$

Substituting $p_0 = p_1$ and reducing,

$$Cp_0 - Cp = v_0\,w_1\,(1+\alpha t_1)\,p$$

$$(C + v_0\,w_1\,(1+\alpha t_1))\,p = Cp_0$$

$$p = \frac{Cp_0}{C + v_0\,w_1(1+\alpha t_1)}$$

Substituting the above values, we have:

$$p = 122.49^{\text{mm}}.$$

By experiments of Regnault, this corresponds to a temperature of 55.8° C. Hence, till the fumes have cooled to this temperature they will not deposit any moisture.

The density of saturated aqueous vapor, or the weight of a cubic meter of aqueous vapor at this temperature, is, from Zeuner's tables by interpolation, $w = .10876$ kg. Hence, the volume of the furnace gases at the point of saturation is:

$$v = \frac{C}{w} = \frac{2784}{.10876} = 25598 \text{ cu. m.}$$

For all temperatures, $t_2$, above 55.8° C., the gases are no longer saturated with aqueous vapor, and obey the combined law, thus:

$$v_2 = v\,\frac{1 + \alpha\,t_2}{1 + \alpha\,t}$$

and the weights of aqueous vapor per cubic meter are found from $w_2 = \frac{C}{v_2}$.

Table XI. is thus calculated from the above for temperatures above 55.8° C., and from Tables IX. and X. for temperatures below it.

TABLE XI.

*Volume of Furnace Gases and Weight Aqueous Vapor.*

| t° C. | Volume Furnace Gases. | Wt. Water per cu. m. | Wt. Water in total Gas. |
|---|---|---|---|
| 0° | 17,491 cu. m. | 0.00475 kg. | 83 kg. |
| 15° | 18,637 " | 0.01290 " | 240 " |
| 20° | 19,091 " | 0.01703 " | 971 " |
| 40° | 21.491 " | 0.05091 " | 1094 " |
| 55.8°* | 25,598 " | 0.10876 " | 2784 " |
| 60° | 25,925 " | 0.10739 " | 2784 " |
| 80° | 27,484 " | 0.10130 " | 2784 " |
| 100° | 29,040 " | 0.09587 " | 2784 " |

* Aqueous dew-point.

*d. Specific Weight of Quicksilver-Vapor.*—Next we have to determine the weight of quicksilver-vapor contained in a cubic meter of the furnace-gases. This weight will, of course, be the same as that of the saturated vapor evaporating into a vacuum of the same volume and at the same temperature. There have been, so far as I am aware, no experimental determinations made in this direction. All the data we have at present are the density-determinations of the vapor above its boiling-point, and the determinations of Regnault and Hagen of the tension of the saturated vapor at various temperatures. Hence the closest estimate that can now be made must depend on the combined law of Gay-Lussac and Mariotte. This law gives, for vapor of water, determinations which differ only in the second and third place of decimals from the more exact values given in Table IX.

The calculation is, of course, similar to that given for the determination of the aqueous dew-point of the fumes. We know the Hg vapor to be 100.7 times that of the same volume of H at the same temperature and pressure.

Now the weight of 1 cu. m. H at 0° C. and 760 mm. is 0.08961 kg. Hence at 357°, the boiling point of quicksilver, and the same pressure as before, a cubic meter of H will weigh $\frac{0.08961}{1+357\,\alpha}$, and consequently the weight $w_1$, of a cubic meter of Hg vapor under the same conditions will be:

$$w_1 = \frac{100.7 \times 0.08961}{1 + 0.003665 \times 357} = 3.3091 \text{ kg.}$$

Next, if

$v_1$ = vol. Hg vapor at $t_1 = 357°$ and $p_1 = 760^{mm}$,
$v$ = " " " $t$ and $p^{mm}$,
$w$ = wt. " " " $t$ " $p^{mm}$, per cu. m.

Then

$$\frac{w}{w_1} = \frac{v_1}{v} = \frac{1 + \alpha t_1}{1 + \alpha t} \cdot \frac{p}{p_1},$$

$$w = w_1 \cdot \frac{1 + \alpha t_1}{1 + \alpha t} \cdot \frac{p}{p_1},$$

$$w = 3.3091 \frac{2.3084}{1 + \alpha t} \cdot \frac{p}{760},$$

$$w = 0.011873 \frac{p}{1 + \alpha t}.$$

Regnault's determinations of the value of $p$, *i.e.*, of the tensions of Hg vapors between 0° and 100° C., have been recently re-made by E. Hagen,* and as they seem to have been made with special care they are used (in calculating the following table) instead of Regnault's, which are invariably higher.

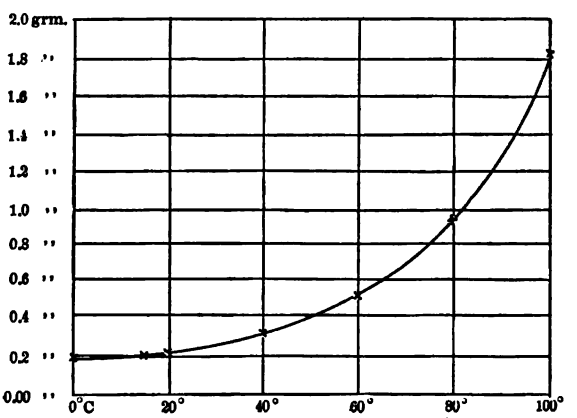
TABLE XII.

*Specific Weight (Wt. of 1 cu. m.) Quicksilver-Vapor.*

| $t$ ° C. | $p$ mm. | $1 + \alpha t$. | $w$ kg. |
|---|---|---|---|
| 0° | 0.015 | 1.0000 | 0.0001781 |
| 15° | 0.0195 | 1.0550 | 0.0002195 |
| 20° | 0.021 | 1.0733 | 0.0002323 |
| 40° | 0.033 | 1.1466 | 0.0003417 |
| 60° | 0.055 | 1.2199 | 0.0005353 |
| 80° | 0.102 | 1.2932 | 0.0009365 |
| 100° | 0.210 | 1.3665 | 0.0018247 |

*Diagram showing Curve of Specific Weight of Quicksilver-Vapor* (From Gay-Lussac and Mariotte's Law).

DIAGRAM A.




The vertical axis gives grammes Hg vapor or thousandths of a kilogramme per cubic meter, and the horizontal axis degrees Centigrade.

The curve plainly shows that the specific vapor weight for temperature below 20° C. does not vary very rapidly for further reductions of temperature.

Let us now determine the vapor-loss per furnace-day for various escape temperatures between 0° and 100° C. We have only to mul-

* *Wied Ann.* 16, p. 610, 1882.

tiply the specific quicksilver weight given in the last column of Table XII. by the corresponding volume given in the second column of Table XI., and we have the required vapor-loss in kilogrammes. Now the ore treated per furnace-day was found to be 18,063 kg., with an actual yield of 2.976 per cent. Hence the quicksilver-yield for this time would be 537.56 kg. The last column of Table XIV. gives the percentage vapor-loss calculated on the basis of actual yield—not content, which is as yet unknown.

TABLE XIII.

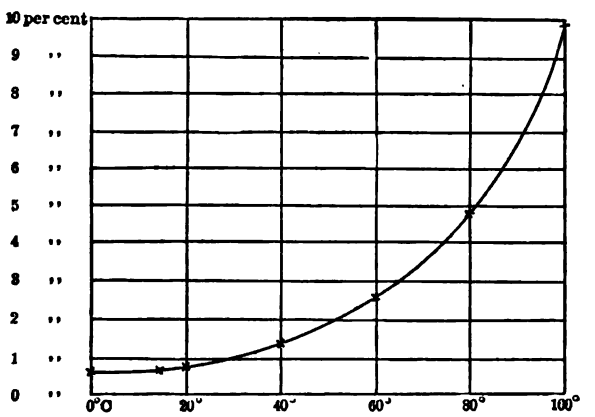
*Vapor-Loss per Furnace-Day at Various Escape-Temperatures.*

| t° C. | Total Vapor Loss per Average Furnace-day. | |
|---|---|---|
| | kg. Hg. | Per cent. of Yield. |
| 0° | 3.115 | 0.58 |
| 15° | 3.249 | 0.60 |
| 20° | 4.435 | 0.83 |
| 40° | 7.344 | 1.37 |
| 60° | 13.878 | 2.58 |
| 80° | 25.737 | 4 79 |
| 100° | 52.989 | 9.86 |

The diagram below shows the curve of percentage vapor loss plotted from the values given in Table XIII.

*Curve of Percentage Vapor Loss (with Double Theoretic Air).*

DIAGRAM B.




The vertical axis gives percentage vapor-loss on basis of *yield;* the horizontal axis gives degrees Centigrade.

It will be noticed that the curve falls more rapidly for low tem-

peratures than the specific vapor-curve of the preceding diagram. This is, of course, due to the contraction of the gases in which the vapors are diffused. It will be noticed that the vapor-loss curve falls very slowly for temperatures below 20° C., and consequently the reduction of vapor-loss by artificial cooling below say 15° C. would effect very little saving.

## VII. Comparison with New Almaden Practice.

As already stated, the only systematic sampling and assays of ore treated at New Almaden were made with the ores of Tierra Furnace No. 8. The results were published in the Annual Report of the Quicksilver Mining Company for 1876, p. 35. From this document I quote as follows:

"This furnace for 39 days' work gave an average yield of 1.40 per cent. quicksilver; car samples were taken of each charge, which were crushed and thoroughly mixed.

"A portion was sent to Mr. H. G. Hanks, Assayer, San Francisco. Of this he writes:—

"'I have made careful assays of samples, with the following result:

"'Quicksilver, 1.51 per cent.

"'Assays verified by several determinations.'

"The assay being 1.51 per cent. and working yield 1.40 per cent. the difference was 0.11 per cent.; the amount flasked of all the quicksilver in the ore was 92.71 per cent., leaving for coating of condensers, pipes, etc., and loss, 7.29 per cent."

Now as the ore treated ran only as high as 1.51, while the average yield of the ore previously considered was 3 per cent., the above results will not be directly applicable. Let us take the results as to ore and fuel, given in the previous paper in the table of working results for Furnace No. 8 for 1882, as they were the same, except as to yield, for 1876. Then we have for Furnace No. 8, per day of 24 hours:

Tierras, 23.424 tons = 46,848 lbs. = 21,250 kg.
Wood, 2.028 cords = 5637.84 lbs. = 2,557 kg.
With a yield of 1.40 per cent.

TABLE XIV.

| No. 8 Tierra, per Furnace-day. | $CO_2$. | $H_2O$. | N. | Excess Air. | $SO_2$. | Product Dry. [Double Air.] |
|---|---|---|---|---|---|---|
| | kg. | kg. | kg. | kg. | kg. | 0° C. 760 mm. cu. m. |
| Wood 2,557 kg. | 3,751 | 1,509 | 9,042 | 11,770 | ..... | 18,206 |
| Ore 21,250 kg. | 2,125 | 2,125 | 1,403 | 1,828 | 850 | 3,931 |
| [Hg 320.875 kg.] | 5,876 | 3,634 | 10,445 | 13,598 | 850 | 22,137 |

We have already seen that in the month of February, 1882, the fumes of No. 9 furnace escaped from the condenser at a temperature of 13.3° C., the outside air being 12.8° C. Probably a fair average air-temperature the year round would be 15° C. To be safe, we shall assume an average *escape-temperature* of 20° C.

Then we shall have as the volume of the escaping fumes, saturated with aqueous vapor—

$$v = v_0 (1 + at) \frac{p_0}{p_0 - p}$$

$$v = 22{,}137\ (1 + 20 \times .003665)\ 1.023 = 24{,}306 \text{ cu. m.}$$

Now 24,306 cu. m. of fumes escaping at 20° C. will carry away $24{,}306 \times 0.0002323$ kg. of Hg vapor, or 5.67 kg. But there were treated to produce this amount of fumes 21,250 kg. of ore containing 1.51 per cent., or 320.875 kg., yielding 1.40 per cent., or 297.5 kg. Hence the vapor-loss is:

$$\frac{5.67}{320.875} = 1.73 \text{ per cent. of the ore-content, or}$$

$$\frac{5.67}{297.5} = 1.91 \text{ per cent. of the ore-yield.}$$

We have seen that the poorest result of the normal roasting showed only 0.05 per cent. of mercury in the residues, while in most cases only traces are reported. Now the method of assay was easily sensitive to 0.01 per cent., and hence a fair allowance for such a careful experimental test would be 0.01 per cent. The clean-up error is not easily ascertained; probably the fairest result will be reached by not attempting to consider it; as the walls, for such a short test, would be about equally saturated before and after the test. Making the above allowances we have:

| | | | |
|---|---|---|---|
| Direct yield (flasked), . . . | | 92.71 pr. ct. ore content. | |
| Residue-loss $\left(\frac{0.01}{1.51} \times 100\right)$, . | 0.66 pr. ct. | | |
| Vapor-loss, . . . . . | 1.73 " | | |
| Mist-loss (by difference), . . | 4.90 " | 7.29 " | " |
| | | 100.00 " | " |

It will be noticed that the mist-loss, as here calculated, is almost three times the vapor loss (2.8 times).

The above results enable us to make an estimate of the total loss of the treatment at New Almaden. We shall assume a residue-loss of 0.01 per cent., which, as before remarked, is probably too high; also that the vapors escape at 20° C.; also that the *mist*-loss is three times the vapor-loss. We have then for the average of all the furnaces for 1882, working on ore which yielded 2.976 per cent., the following losses.

| | | |
|---|---|---|
| Residue-loss $\left(\frac{0.01}{2.976} \times 100\right)$, . . . | 0.34 per cent. of yield. | |
| Vapor-loss at 20° C. (Table XIV.), . . | 0.83 " | " |
| Mist-loss (3 times vapor loss), . . . | 2.49 " | " |
| | 3.66 per cent. of yield. | |

Reducing this to basis of ore-content, and we have total loss

$$= \frac{0.0366}{1 + 0.0366} = 0.03531.$$

Similarly we obtain:

| | | |
|---|---|---|
| Residue-loss, . . . . . | 0.328 per cent. ore-content. | |
| Vapor-loss, . . . . . | 0.801 " | " |
| Mist-loss, . . . . . | 2.402 " | " |
| | 3.531 per cent. ore-content. | |

Now in the preceding calculations we have made several assumptions, most of which are certainly safe as outside estimates; on the other hand we have assumed the correctness of the combined law for gas as applied to quicksilver-vapor, in calculating the vapor-loss. We have seen that the law applies very closely to aqueous vapor between the limits of 0° and 100° C. It is possible, but hardly probable, that the variation of the quicksilver-vapor from the above law will sensibly affect the above result. Regarding the pressure under which the gases exist in the condensers, we have assumed 760 mm. This is of course too high, as the pressure must be less to maintain the draft. However, if the pressure were only 700 mm. (instead of 760), the increase of volume of the gases and the consequent increase of vapor loss would be only one per cent. of

the above calculated result. The last mentioned increment will be more than offset by the diminution of volume by the absorbtion of $SO_2$, $CO_2$, etc., from the furnace-gas by the condensed water. The most important consideration, however, is the assumption that only double the theoretic air-volume is used. But, even assuming that three times the theoretic amount of air was used, which is certainly quite beyond the necessary amount, the increase of volume of the furnace gases, and the consequent loss, would be less than one-third the present loss. Hence 5 per cent. of the ore-content is an outside estimate of the minimum possible average loss of treatment under the conditions in effect at New Almaden, and 4 per cent. is probably nearer the truth.. This result would be considered good work for any metallurgical operation, even for silver- and gold-extraction, and it is, therefore, interesting and important, before accepting it, to compare it with the results of work elsewhere.

## VIII. Comparison with Results at Idria, Austria.

Fortunately, the publication of the Idria officials before cited furnishes abundant data for such a comparison, and in spite of an apparent contradiction they furnish full corroboration of the above results. On page 51 of the translation, by the author, occurs the statement:

"The gases escaping from the chimney [leading from the combined condensing-systems of all the furnaces], have, according to the investigation of the official commission, a velocity of 1.4 m. per second, and there passes therefore, through a cross-section of 1.331 sq. meters, a volume of 1.8634 cub. m. or 1863 liters per second, and in twenty-four hours, 160,997,760; or in round numbers, 161 million liters of gas pass through the chimney. There were found in 1,000 liters of chimney gases .00356 grammes of quicksilver, hence in twenty-four hours there will escape 573.16 grammes of quicksilver."

On p. 42 of the translation, it is stated that the number of reverberatory furnace-days was 314½, on p. 43, that the works are shut down during the month of August, for repairs and cleaning of condensers and flues. Hence 330 working days may be safely taken as the outside limit of the year's work.

Now if we take the estimate of the contents of the fumes made by the official commission, viz., 573.16 grammes of quicksilver lost per day, we shall have a total annual loss for the year, of 189.14 kgs.

This is evidently wrong, for on p. 55 of the translation occurs the

statement that "In the year 1879 there were treated in all, 409,329 met. centners of ore and metallurgical products, with a quicksilver-content of 1.296 per cent., containing 5,308 metrical cent. of quicksilver, and there were produced 4,877 metrical centners of quicksilver, with a loss of 431 met. cent., or 8.12 per cent." Now the amount lost, 189.14 kg., as determined by the official commission, divided by 43,100 kg., the total loss, gives less than $\frac{1}{200}$ of the total loss.

There is plainly an error somewhere. All the above figures have been carefully verified in the original. It is not likely to be a mere typographical error. The values given in the paragraph concerning the determinations of the official commission agree among themselves, but not with the working returns of the works. Most probably the error occurred in determining the quicksilver-content of the escaping fumes. The method by which this was done is not given. It is not an easy matter to make such tests. The total amount of quicksilver found by the commission in a cubic meter (1000 liters) of fumes, was .00356 grammes. The amount of quicksilver-vapor alone, according to the calculation made in Table XII., is, at an escape-temperature of 20° C., 0.2323 grammes per cubic meter of gas. But the ordinary methods of gas-analysis would of course fail entirely to estimate such small quantities with any degree of certainty. In the presence of aqueous moisture, flue-dust, and the empyreumatic matters in the fumes, the amalgamation even of fine gold is effected with difficulty, as I have often verified by experiment.

In order to make sure that the error was not a typographical one, I have carefully tabulated the results given separately for each furnace in the Idria memoir. The pages refer to the translation.

## TABLE XV.

*Yield of Idria Furnaces for* 1879.

| Furnace. | pp. | Ore. | | Hg. Cont. | Yield. | Loss. | |
|---|---|---|---|---|---|---|---|
| | | Kind. | Metr. cent. @ 100 kg. | Metr. cent. @ 100 kg. | Metr. cent. @ 100 kg. | Metr. cent. | Per cent. |
| Reverberat'y, | 44, | "Griesen," | 246,412 | 2022 | 1884 | 138 | 6.82 |
| Shaft furnac's | 47, | "Stufen," | 141,289 | 594 | 499 | 95 | [15.99] |
| Cont. reverb., | 48, | Crushed ores, | 11,201 | 960 | 885 | 75 | [7.81] |
| Muffles, | 50, | "Erze," | 8,102 | 870 | 792 | 78 | [8.98] |
| " | 54, | Soot, | 2,324 | 862 | 817 | 45 | [5.22] |
| | | | 409,328 | 5308 | 4877 | 431 | [8.12] |

It will be noticed that these figures agree entirely with the sum total previously given, except that the amount of ore and products differs by one metrical centner, an unessential error, the above sum total being 409,328 instead of 409,329.

Now on page 42 of translation, occurs the statement that the average of the residues shows a content of 0.001 per cent. quicksilver. This would make the residue loss for the year, 4.09328 metr. cent. or 409.328 kg. Subtracting this from the total loss of 431 metr. cent., we have for the total chimney-loss 426.91 metr. cent., or 42,691 kg. of Hg.

Now if we assume as correct, the measurement of the volume of fumes discharged by the chimney, as determined by the official commission, viz., 161,000 cubic meters per 24 hours; if also we suppose the average escape-temperature to be 20° C. [the temperature is not given in the memoir*], we have per day of 24 hours:

161,000 × 0.0002323 = 37.40 kg., and for the year of 330 working days, 12342.1 kg.

Consequently the losses will be distributed as follows:

TABLE XVI.

*Losses at Idria for* 1879.

| | kg. | Per ct. Hg. Content. | Per ct. Hg. Yield. |
|---|---|---|---|
| Furnace (residue)-loss, | 409.33 | 0.077 per cent. | 0.084 per cent. |
| Vapor-loss, . . . . | 12,342.10 | 2.325 " " | 2.531 " " |
| Mist-loss, by difference, | 30,348.57 | 5.718 " " | 6.223 " " |
| Total loss, . . . . | 43,100.00 | 8.120 " " | 8.838 " " |

This loss is evidently about twice as great as that estimated for New Almaden. This, however, is a natural result of treating poorer ore. The New Almaden ore-*content* would average 3.085 per cent. as against 1.296 per cent. at Idria. The loss is dependent on the volume of fumes, at the same escape-temperature; and the latter, of course depends on the amount of fuel and ore used, and not on the richness of the ore. Hence the percentage-loss will be less on rich than on poor ore.

* It will be remembered that the vapor-loss from 30° down to 0° C. showed but little variation.

The quantity of ore treated at New Almaden in 1882 was $1811.75 \times 18{,}063$ kg. $= 327{,}257$ metr. cent. as against 407,328 metr. cent. treated at Idria. As to volume of fumes, assuming escape temperature to be 20° in both cases, at New Almaden we have $1811.75 \times 19{,}091 = 34{,}588{,}119$ cu. m. as against $330 \times 161{,}000 = 53{,}130{,}000$ cu. m. at Idria. Hence with an ore less than half as rich as that at New Almaden a loss of 8.12 per cent. is as good a metallurgical result as a loss of only 4 per cent. at New Almaden.

It will be noticed that the *mist-loss* at Idria is about two and a half times the *vapor-loss*, while the result obtained for New Almaden was two and eight-tenth times. The agreement is as close as may be expected for such calculations.

## IX. Comparison with Results at Almaden, Spain.

In the *Annales des Mines* for 1878 * appeared an interesting and able memoir *Sur les Mines et Usines d'Almaden*, by M. H. Kuss, E.M. This memoir contains a chapter bearing on the present inquiry entitled "Losses of Treatment," the whole of which is well worth reading; but from it only a few extracts can be made here.

The author begins by referring to the exaggerated estimates that had been made of the losses of treatment at Almaden, due to badly-taken assay-samples of the ores. The average value of the Almaden ores was wrongly estimated at 14 per cent. For instance, MM. Fernando Bernaldez and Ramon Rua Figueroa, in an otherwise able memoir printed by royal order in 1861, declared the loss to be 53.40 per cent. of the ore-content in the so-called Idria furnace, and 49.82 per cent. in the Bustamente furnace. Others variously estimated the loss as between 30 and 40 per cent.

In 1867, M. Emile Pellet, a French engineer, incited by the broad margin of profit left open to inventors by these figures, devised a new furnace and condensing-system in which a water-chamber and a shower of water-spray played an important part. In 1867 he secured permission to make a trial of his system, and in 1869 a comparative test was instituted between his and the old "Idria" furnace. In case of success, he was to receive the entire profit resulting from the introduction of his system for one year. These profits were estimated at 3,730,000 francs. These facts are cited to show the inducements M. Pellet had to see that the comparative tests were

* 7 Série Mem. t. 13, p. 39. *The Mines and Works of Almaden*, translated by S. B. Christy and published by Dewey & Co., S. F., 1879.

fairly made. From the description given by M. Kuss of the precautions taken, and from the fact that M. Pellet declared himself fully satisfied with them, the results seem fully worthy of credence.

To be brief, the Pellet furnace showed a loss of 27.62 per cent., while the "Idria" furnace showed a loss of only 5.59 per cent. Besides, the expense of treatment was nearly three times as great by the Pellet system as with the "Idria" system, and 35 workmen were badly salivated at the former furnace. Condemned a first time, M. Pellet secured a second trial, which was made in 1872. The result of this was a final rejection of the Pellet system as a failure, but what was more important, the losses in the old "Idria" and Bustamente intermittent furnaces were shown to be 5.50 and 4.95 per cent. respectively. These results were obtained, it is true, in careful tests and are probably better than the current results.

Not content with these determinations, based on assays and sample-taking, M. Kuss makes what may be called a synthetic calculation, based on determinations made in the large way. He gives as the result of the whole discussion:

1. "That the average content of the Almaden ores does not exceed 8 or 9 per cent.

2. "That the loss of mercury indicated by the *assays* does not go beyond 6 per cent. for the "Idria" furnace and 5 per cent. for the Bustamente.

3. "That the loss of mercury contained, calculating this synthetically from the most elevated figures, does not go beyond 10 per cent.; and, finally,

4. "Regarding the apparatus at Almaden, without calling them rational in design, it must be admitted that their defects have been exaggerated, and that, conducted with care, they give, with a rich ore, excellent results."

In the *Annales des Mines*, 7 Série, t. 15, p. 524, 1879, M. Kuss gives an abstract of the work of MM. L. de la Escosura and F. de Botella which was published in 1878 under the title *Histoire de la Métallurgie du Mercure en Espagne.* Four charges of 36.428 metric tons of a content of 9.55 per cent. (richer than the average ore by one per cent.) were treated in the Bustamente furnace with a loss of 4.41 per cent. of the mercury content. Six charges of 139.74 metric tons containing 10.02 per cent. were treated in the "Idria" furnace with a loss of 6.20 per cent. of the mercury contained.*

* It will be noticed in passing that the Bustamente furnace invariably gives better results than the "Idria" furnace. This undoubtedly is due to the superiority

I have not made a calculation of the vapor-loss for the Almaden furnaces, as I have not sufficient data for the determination of the volume of the fumes. This is particularly difficult without numerous actual tests, on account of the intermittent nature of the operation.

It should, however, be remarked that a loss of 4 to 6 per cent. at Almaden on 9 per cent. ore is not so good a metallurgical result as those obtained at Idria and New Almaden. For, under given furnace- and condenser-conditions, the *absolute loss* is the same (so long as any quicksilver at all is produced), no matter what the content of the ore. The *percentage* loss, however, depends on the ore-content. Hence, working conditions being the same, the Almaden losses would be 12 to 15 per cent. if they worked on 3 per cent. ore as at New Almaden, and 24 to 30 per cent. if they worked on 1.5 per cent. ore as at Idria.

Moreover, on account of its large production, the absolute loss at a low percentage is greater at Almaden than at any other place in the world. And the net profit resulting from the introduction of improved condensing appliances would be equally great. Thus, in 1884, the production of Almaden was 43,099 flasks at 76.03 lbs. avoird., or 3,276,817 lbs. Supposing a working loss of 5 per cent., we have the original content of the ore 3,449,281 lbs., hence the absolute loss amounts to 172,464 lbs. At 40 cts. this amounts to a money value of $68,985. Even should a saving of but one per cent. be effected by improved appliances, it would amount to over $13,000 per year.

It must be evident from the foregoing that quicksilver-condensation as practiced at such places as New Almaden and Idria is by no means the imperfect process that it is sometimes represented to

---

of the aludels over the masonry condensation-chambers of the Idria furnace. The former have the decided advantages of offering more cooling and friction surface to the fumes. The alternate contractions and expansions of the aludels are also favorable to eddies and furnish dead spaces for the settling of the fumes. M. Kuss also states that the air drawn in through apertures in the bellies of the aludels, helps to cool the fumes, and that their stoppage increases the loss by ½ per cent. Certainly the increased volume of air must increase both vapor- and mist-loss, and the fact that a saving results, shows only that the aludels were insufficient in number for the purpose of cooling. This conclusion is verified by temperature tests of MM. Escosura and Botella which show that the last aludels have a temperature from 3° to 27° above that of the surrounding air. However, this difficulty is easily remedied by increasing their number, and the aludels are certainly better condensers than they have been generally considered.

be, and results are obtained in practice that compare favorably with those obtained with other metals.

## X. Future Improvements in Quicksilver-Condensation.

It would lead too far from the purpose of this paper to attempt any adequate treatment of this subject. A few important conclusions may, however, be drawn from the preceding discussion.

1. *The volume of permanent gases passing through the condensers should be reduced to a minimum.* The reduction in the vapor-loss would be in the direct ratio of this reduction, and the reduction of the mist-loss in a greater ratio. That is, if the volume of escaping fumes were reduced one-half, the vapor-loss would be but half the present loss, and the mist-loss probably not more than one-fourth. For the mist-loss is evidently a function of the velocity, and hence of the volume, of the escaping fumes, and, other things equal, probably varies at least as the square of the velocity. In addition, the reduction of the amount of permanent gases would also reduce the number of heat-units that must be removed by the condensing system. Hence the efficiency of the system would be increased, or the same cooling effect might be reached by a smaller system.

It must be remembered, however, that the conditions for perfect condensation and economical reduction are in direct opposition to each other. The most perfect condensation may certainly be effected with the old retort-system and the use of quicklime. This method is at the same time the most expensive system of reduction. On the other hand, the reduction-system now in use at New Almaden may certainly be regarded as the most economical system of reduction that can be employed in the present state of the art; but the volume of the fumes and the consequent necessary percentage-loss, is much greater than would be the case with a properly conducted retort-system. As the object of quicksilver-reduction is commercial profit and not scientific test-making, a careful adjustment of those conflicting interests must decide whether or not there is any room for improvement in this direction.

One simple method which might be successfully applied in large establishments, would be the use of gas instead of a solid fuel. The Lowe or Lowe-Strong gas would be the cheapest, and also the best, on account of its high calorific effect per unit volume. By this means, only about the theoretic air-volume would be required, and the volume of condenser-fumes could be reduced $\frac{1}{3}$ or $\frac{1}{4}$.

The most complete reduction of vapor-volume would follow the introduction of continuously acting retort- or muffle-systems heated from the outside, in which only air enough was admitted to the interior of the retort to oxidize the cinnabar, pyrite, etc., and from which were excluded all gases from the furnace. As will be seen from Table VII., we should have, per average furnace-day, to deal with only about 3300 cu. meters of permanent gas instead of 17,400 cu. meters. This would be of great advantage in condensation, but the consumption of fuel would be largely increased, the furnace construction difficult, and the repairs expensive.

2. *Next in importance is sufficient volume for sedimentation, and surface for friction and cooling action.* The mist-loss in the present practice seems, from the examples cited, to be from two to three times as great as the vapor-loss. It would seem possible to make some reduction in this direction, by reducing the velocity of escape, and by the use of greater friction surfaces. The principle of the Pelouze and Audoin condenser used for removing coal-tar from coal-gas might be useful. At the same time it should be remarked that these condensers give much difficulty at the gas-works, from being choked with tar. The mercurial soot would probably give the same difficulty in quicksilver-works, and of course either iron or glass construction would be difficult.

3. *The temperature of escape should not exceed* 15° *or* 20° *C.* It has been already seen that, below fifteen degrees, the reduction of vapor-loss between that temperature and zero is so small as to be unimportant. This cooling would of course have no effect upon the mist-loss. Hence the use of ice-machines (so often recommended) can not be expected to materially increase the yield of the condensers.*

In situations where fuel was cheap, or water-power abundant, the use of ice-machines might be justified on account of the reduction in the size of the condensing-plant that would result, but no great economy should be expected from their use.

There is one point which might militate against their use: the sudden condensation of the quicksilver-vapor might lead to the formation of smaller globules than if the cooling took place more gradually, and a greater mist-loss might ensue.

As a cooling agent, water is the best, either as a bath about iron

* I have made the calculation with ruling prices for fuel and labor at New Almaden, and find that the ice-machines would have to effect a saving of 5 per cent. of the present yield, in order to cover running expenses. This is, as above shown, impossible.

condensers, or, better, as a spray in a current of air, so as to utilize the evaporation of the water. Sprays coming in contact with the fumes have never been successful, on account of the difficulty of separating the floured quicksilver from the water.

Air is the cheapest cooling agent, and the condensers, where not water-cooled, should be so constructed as to secure a strong natural circulation of the air about them.

4. *Material for construction.* There is a fine field for invention in the discovery of some substance strong enough to be made very thin, a good conductor of heat, which will resist abrasion and the alternate action of heat and cold without cracking or leakage, and which will resist, at the same time, the action of quicksilver and warm dilute sulphuric acid. As already mentioned, Bower-Barff rustless iron seems the most promising material.

5. *Next must be mentioned the use of an artificial draft.* This is all the more necessary as the cooling of the gases becomes more perfect, and their temperature approaches that of the outside air. Auxiliary fire-places and steam-jets are often used for this purpose, both of which are wasteful of power and heat the side-hill flues, putting an effectual stop to further condensation. A simple suction-fan, such as the Guibal, or a modified Root blower made of wood, and constructed with a view to ease of repairs, is the best arrangement. As above remarked, more draft than is necessary to maintain combustion and to protect the men from salivation should not be used, as the chimney-loss would be thus increased.

6. *The condensers should be easily and completely cleaned without interrupting the action of the furnaces.*

The above outline of the principal conditions that must be complied with in order to improve on the existing devices, shows some of the great difficulties in the way of future improvement. And while it is not impossible that some of them may be successfully overcome, it does not seem probable that any great commercial profit will result from their introduction at such establishments as those of Idria and New Almaden.

In concluding this account of the quicksilver reduction-works of New Almaden, I must take occasion to express my thanks to all the officers of the company for their kindness and coöperation. I am particularly indebted to the assistance of the superintendent, Mr. Hennen Jennings, and most of all to the manager, Mr. J. B. Randol, to whose untiring efforts during the fourteen years of his administration, is due the existence of all the important devices described in these papers, as well as the present high efficiency of the reduction-works.

# APPENDIX.

## RECENT IMPROVEMENTS IN DRAFT-ARRANGEMENT.

Since the above was written, some important changes have been made in the draft arrangements of the furnaces on the west bank of Alamitos Creek. All the fire-drafts have here been given up, and the fumes from Furnaces 3, 8, 6, 7, and 9 are led to the Guibal fan before mentioned, and thence up the side-hill flue formerly used by Furnaces 3, 6, and 8 only. By this means the fumes are forced to pass a distance of over 800 feet after leaving the condensers. This important addition to the condensing appliances will probably result in an increased saving of quicksilver as soon as the speed of the fan is properly adjusted.

It was at first feared that the single fan would not manage all the fumes, but it has proved more than sufficient, and could most likely manage the fumes from Nos. 1 and 2 furnaces. It will be remembered that formerly, when only Nos. 3, 6, and 8 were connected with the fan, it made 60 to 70 revolutions per minute: now it runs at from 97 to 112 per minute, according as No. 6 is shut down or is in operation.

It takes only 2 or 3 horse-power to run the fan, which is kept in operation day and night by a 6 horse-power vertical engine. The latter also operates a pump which elevates water from the creek to a large tank 80 feet above the works, where it furnishes power for the elevators, and water for the condensers. By this arrangement, Mr. Jennings has been able to avoid pumping the water from the mine (formerly used at the works) several hundred feet higher than otherwise necessary. The total running expenses for fuel, oil, lights, and labor, do not exceed ten dollars per day, while the amount saved at the mine exceeds that sum considerably.

The draft of the various furnaces is regulated by means of dampers, and the operation of the furnaces is found to be under much better control than formerly. The system is, however, too new to be adjusted for the best results as yet. That too much draft is now used, will be shown later.

## MEAN ANNUAL TEMPERATURE.

In the foregoing discussion we have assumed a mean annual day

and night temperature of the outside air at the Hacienda of 15° C., and a mean annual escape-temperature of the fumes of 20° C. As it has been impossible to get sufficient data for certainty on these points, it will be, perhaps, worth while to mention the facts on which this estimate is based.

Temperatures have not been recorded at the Hacienda very regularly; most observations have been merely of extremes of heat and cold, and have been taken in the daytime only.

The records during 1882, 1883, 1884, and up to September, 1885, show in all some 150 observations. Of these, the highest day temperatures occur in *May*, *June*, *July*, *August*, and *September*. The highest recorded temperatures occur between 1 and 3 P.M. Thus: 41° C. (106° F.), appears once; 39.4° C. (103° F.), appears once; 38.9° C. (102° F.), appears once; 38.3° C. (101° F.). appears three times; 37.8° C. (100° F.), appears three times; while 24° to 37° C. (75° to 99° F.), appear most frequently during these months. The above may be regarded as maxima, as all are taken between 1 and 3 P.M. The lowest temperatures occurring in these records are in *November*, *December*, *January*, *February*, and *March*. Thus: —5.6° C. (22° F.), occurs once (January, 1882, 7 A.M.); —4.4° C. (24° F.), occurs once; —3.3° C. (26° F.), occurs twice; —2.8° C. (27° F.), occurs once (7 A.M.); —2.2° C. (28° F.), occurs once; —1.8° C. (29° F.), occurs once; 1.1° C. (30° F.), occurs five times; —0.6° C. (31° F.), over four times.

The remarks "frost," "snow," or "ice" occur fifteen times in addition, indicating a minimum temperature probably below 0° C. As no night temperatures are in any case given, the minima probably were below any here recorded. The highest recorded winter temperature is (2 P.M., March, 1883) 23.9° C. (75° F.). A careful examination of these fragmentary records leads me to regard the assumption of 15° C. (59° F.) for the mean annual day and night temperature as very near the truth.

### MEAN ESCAPE-TEMPERATURE OF FUMES.

It has, of course, been even more difficult to ascertain these figures. The following determinations were made in September of this year (1885) to supplement those already cited by Mr. Smedburg, taken in February, 1880.

The outside air-temperatures (in the shade) during the time the observations were made, were as follows:

OUTSIDE AIR-TEMPERATURES (IN THE SHADE).

| Date. | Place. | Hour. | Temperature. | |
|---|---|---|---|---|
| | | | Deg. C. | Deg. F. |
| Sept. 12, 1885. | Manager's residence. | 8 P.M. | 17.7 | 64 |
| " " | " " | 10 P.M. | 15.5 | 60 |
| Sept. 13, " | " " | 4.30 A.M. | 15 | 59 |
| " " | " " | 7 A.M. | 18 | 64.4 |
| " " | Hacienda office. | 8 A.M. | 21.2 | 70 |
| " " | " " | 1 P.M. | 30.3 | 86.5 |
| " " | " " | 2 P.M. | 31.9 | 89.5 |
| " " | " " | 4 30 P.M. | 28.6 | 83 |
| " " | Manager's residence. | 5 30 P.M. | 26 6 | 80 |
| " " | " " | 7.30 P.M. | 20 | 68 |
| " " | Hacienda office. | 8.30 P.M. | 19.2 | 67 |
| " " | " " | 9 P.M. | 18.3 | 65 |
| Sept. 14, " | " " | 4 A.M. | 16.3 | 61 |
| " " | Bridge (wind down cañon) | 4.30 A.M. | 13.5 | 56 |
| " " | Top flue of No. 2. | 4.50 A.M. | 12.9 | 55 |
| Average air temperature during this time..... | | | 20.3° C. | 68.6° F. |

The flue-temperatures of the fumes escaping from Furnaces Nos. 3, 8, 7, and 9 were taken through a hole in the man-plate just above the Guibal fan; in Furnaces Nos. 1 and 2, at the man-plates just beyond the last condensers. The results appear in the table on opposite page.

Averaging the 15 *air-temperatures* we have, as before stated, 20.3° C., and averaging the 9 air-temperature observations made at the time of the flue determinations, we have 20.8° C. To get the average *escape-temperatures* for all the furnaces during this time, we must make allowance for the volume of fumes discharged through the several flues. As this volume varies roughly with the amount of ore treated, we may find the average closely enough as follows:

| | | |
|---|---|---|
| No. 1, | 30 2° C. and 36 tons per day, | 1087.20 |
| No. 2, | 21 3° C. and 12 tons per day, | 255.60 |
| Nos. 3, 8, 7 and 9, | 29.43° C. and 80 tons per day, | 2354.40 |
| | 128 tons per day, | 3697.20 |

Average escape-temperature (September, 1885), 28.9° C.

In other words, the average air-temperature during the time of making tests being 20.8° C., that of the escaping fumes was 28.9°, or 8.1° C. above that of the air.

Now with an average annual air-temperature of 15° C., an average escape-temperature of 20° C. does not seem unreasonable, particularly

ESCAPE-TEMPERATURE OF FUMES.

| Furnace. | Day. | Hour. | Temperature of outside air (in shade). | Temperature of air at end of condensing rooms (6 feet above floor). | Temperature of escape from condensers. |
|---|---|---|---|---|---|
| No. 1 | Sept. 13, 1885. | 4 P.M. | 28.6° C. | 28.4° C. | 33.7° C. |
| | " 13, " | 9 P.M. | 18.3° | 18.7° | 29.5° |
| | " 14, " | 4.30 A.M. | 13.2° | 14.7° | 27.5° |
| Average | | | 20.03° C. | 20.60° C. | 30.20° C. |
| No. 2 | Sept. 13, 1885. | 4.30 P.M. | 28 6° C. | 28 4° C. | 28.5° C. |
| | " 13, " | 9.30 P.M. | 18 3° | 18.7° | 20° |
| | " 14, " | 4.50 A.M. | 12.9° | 14.7° | 15.5° |
| Average | | | 19.90° C. | 20.60° C. | 21 30° C. |
| Nos. 3, 8, 7, 9 | Sept. 13, 1885. | 2.45 P.M. | 31.9° C. | 28.9° C. | 30.5° C.* |
| | " 13, " | 8.30 P.M. | 19.2° | 22° | 29.8° |
| | " 14, " | 4.15 A.M. | 16.3° | 16.4° | 28° |
| Average | | | 22.46° C. | 22.43° C. | 29.43° C. |

* It will be noticed that this temperature is lower than that of the outside air at the same time. This is accounted for by the fact that the temperature of the air circulating about the condensers was below that of the air on the hill-side near the flue.

as the efficiency of the condensing system must increase with lower air- and water-temperatures. This is more especially true where water is largely used for cooling, as a fall of one degree in its temperature is equivalent to a fall of four degrees in an equal *weight* of air.

If we average the above observed result (28.9° C.) for September with that obtained by Mr. Smedberg for February (13.3° C.), we have an average escape-temperature of 21.1° C. In this calculation the intermittent furnace No. 6 is not included. But, as this runs less than one-third of the time, and during another third of the time is throwing cool air into the condensers, its probable effect will be to reduce these figures. Should, however, the average annual escape-temperature run as high as 30° C., it would have, as may be seen from Diagram B, in the foregoing paper, a very slight effect on the vapor-loss; and the effect on the mist-loss would be also small.

## VOLUME OF ESCAPING FUMES.

With a view to determine whether or not an excess of draft was used in the new arrangement of the flues, the following experiments were undertaken. In these I was assisted by my former student, Mr. Eugene Hoefer (now Hacienda foreman at New Almaden). The point selected for the tests was the first man-hole above the Guibal fan. At this point the fumes were tolerably well mixed, and the velocities sufficiently steady. The man-hole was covered by a tightly fitting wooden cover with an aperture large enough to admit the anemometer. During the observations, this hole was tightly covered by cloths. The anemometer was fitted to a graduated wooden rod, so that its positions in the flue could be determined by plotting. The instrument used was White's (Glasgow) vane-anemometer.

The flue was a cylinder of brick, 5 feet interior diameter, with an area of 19.64 square feet. This area was reduced somewhat by accumulations of soot on the sides and bottom, for which no allowance was made. Also, the velocities had to be taken some distance from the walls, so that the instrument would not become stopped by the soot. Consequently, the results must be somewhat above the real average velocities.

The positions of the anemometer were plotted to scale on the cross-sections of the flue, and the maximum velocity found to be one-third of the radius above the center of the flue. The cross-section of the flue was then divided into two halves by the horizontal diameter,

and the velocities for each half were averaged, and these separately multiplied into the half area of the flue for the total volumes passing.

From what has just been said regarding the absence of velocity determinations near the walls, and the reduction of the effective area of the flue by soot, these results must evidently be somewhat too high; but no reliable correction could be applied.

*Experiment made September* 14, 1885, 4.15 *P.M.* (*Furnaces* 3, 8, 7, 9 *running*).

Barometer 753 mm.; condenser-room, 27.7° C.; pressure in flue alternately greater and less than outside air, generally less; fumes, 30° C.; the Guibal fan made 97 revolutions per minute; highest recorded velocity of fumes, 328 feet per minute; lowest recorded velocity of fumes, 225 feet per minute; average velocity of upper half, 267 feet per minute; average velocity of lower half, 227 feet per minute; volume of fumes passing at this rate per 24 hours, 197,797 cubic meters.

Now at this time the quantity of ore and fuel burned by these furnaces was as follows:

*Furnaces* 3, 8, 7 *and* 9.

| Per 24 Hours. | Wood. | Coal. | Coke and Charc'l. | Ore. |
|---|---|---|---|---|
| Furnace. | Cords. | Pounds. | Pounds. | Tons. |
| No. 7..... | 0.594 | 111 | 212 | 9.569 |
| No. 9..... | 0.617 | 77 | 210 | 9.570 |
| No. 3..... | 1.569 | 449 | 527 | 35.994 |
| No. 8..... | 2.028 | ..... | ..... | 23.424 |
| ..... | 4.808 | 637 | 949 | 78.557 |

Converting these into kilogrammes we find from Table VI. the amount of fumes produced on the supposition that only double theoretic air was used.

| Per 24 Hours. | Weight. kg. | Vol. Fumes at 0° C., 760 mm. Per kg. in cu. m. | Vol. Fumes (Dry) at 0° C., 760 mm. Cu. meters. |
|---|---|---|---|
| Wood | 6,023 | 7.120 | 42,884 |
| Coal | 289 | 13.660 | 3,948 |
| Charcoal and coke | 430 | 15.128 | 6,823 |
| Ore | 71,266 | 0.185 | 13,184 |
| | | Total volume, $v_0 = 66{,}839$ cu.m. | |

Next we find the volume of the gases saturated with aqueous vapor at temperature 30° C., barometric pressure $p = 753$ mm.

$$v = v_0(1 + at)\,\frac{p^\circ}{p_0 - p}\cdot\frac{p^\circ}{p_1},$$

$v = 66{,}839 \times 1.011 \times 1.043 \times 1.009 = 71{,}135$ cubic meters.

This value of $v$ divided into the measured volume, 197,797 cubic meters, shows the actual volume of fumes passing to be 2.78 times the volume resulting from combustion with double the theoretic air.

*Experiments made September* 15, 1885, 2 *P.M.* (*Furnaces* 6, 3, 8, 7, *and* 9 *running*).

Barometer 749 mm.; condenser room, 27.7° C.; pressure in flue alternately greater and less than outside air; temperature of fumes, 32° C. The Guibal fan made 112 revolutions; highest recorded velocity, 418 feet per minute; lowest recorded velocity, 303 feet per minute; average of recorded velocities, upper half, 379 feet per minute; lower half, 314 feet per minute.

Now the volume of fumes formerly passing was increased by the fumes of No. 6, which had been started. This furnace consumed per day 3 cords of wood, and during a firing-time of 4.45 days roasted 88.405 tons of ore, or per day, 19.866 tons. Adding the quantity of fumes produced by the combustion of this amount of wood, and by the distillation of this amount of ore, we have for all these furnaces per 24 hours (using double theoretic air)—

*Furnaces* 6, 3, 8, 7 *and* 9.

| | Weight. | Vol. Fumes at 0° C., 760 mm. | Vol. Fumes (Dry) at 0° C., 760 mm. |
|---|---|---|---|
| Per 24 Hours. | kg. | Per kg. in cu. m. | Cu. meters. |
| Wood | 9,846 | 7,120 | 70,103 |
| Coal | 289 | 13,660 | 3,948 |
| Charcoal and coke | 430 | 15,128 | 6,823 |
| Ore | 89,289 | 0,185 | 16,518 |
| | | Total volume, $v_0 = 97,392$ cu. m. | |

As before, calculating the volume to which $v_0$ would expand when saturated with aqueous vapor at 32° C. and 749 mm., we have for the volume of gas escaping in 24 hours, if double the theoretic air were used, 115,777 cubic meters, and hence the measured quantity 273,394 cubic meters is 2.36 times this amount.*

Now, even supposing the measured quantity of fumes to be 20 per cent. too high, owing to lack of velocity-determinations next the walls, and the reduction of flue-area by soot-accumulations, it is evident that the volume of fumes now passing through the fan is *double* that necessary for complete combustion, supposing double theoretic air to be used. From this it follows that the present speed of the fan (97 to 112 revolutions per minute) is entirely too high, and that it should be reduced as far as possible, consistent with the proper working of the furnaces. That the latter can be made to work properly on double the theoretic air has been shown by Mr. Smedberg's experiments.

There is, however, another cause leading to an excess of air in the condensing-system not hitherto mentioned, viz., inward leakage. In any large and complicated condensing-system there must be many apertures at man-holes and joints, particularly with the wood and glass condensers. Now the interior pressure of the condensers must be kept lower than that of the outside air, in order to maintain combustion in the furnaces, and to prevent leakage of quicksilver vapor

* Measurements of the fumes discharged from the condensers of Furnaces Nos. 1 and 2 were attempted, but had to be given up, as the velocity of escape was less than 50 feet per minute, the lowest velocity recorded by the anemometer.

from them, and consequent loss and salivation of the workmen. Hence, it follows that the inward leakage of air into the condensers and the augmentation of the volume of the fumes may be easily considerable unless every precaution is taken to prevent it.

Now, supposing the volume of fumes to remain double that theoretically calculated, the actual losses will then be double the amounts calculated as the minimum possible loss of the system. This would make the total actual loss of quicksilver 8 or 10 per cent. of the content on the 3 per cent. ore treated in 1882, or, with the same absolute loss, 12.8 to 16 per cent. of the content on 1.871 per cent. ore, which was the average content of the ore treated in 1884 and 1885.

It seems probable, however, that when the speed of the fan is properly adjusted (as is now being done) and precautions against air-leakage into the system are taken, the volume of escaping fumes may be made to approach the volume calculated with double theoretic air. In this case the total losses would approximate 4 or 5 per cent. of the content on 3 per cent. ore, and 6 to 8 per cent. on 1.871 per cent. ore.

As a final result of this whole study it seems that attention in quicksilver metallurgy has hitherto been too exclusively given to avoiding the residue-loss. As pointed out, this has been successfully accomplished in all the best establishments, but only by long continued roasting at the expense of considerable fuel; all of which causes augment the volume of the fumes, and hence the chimney-loss. In other words, in seeking to avoid Scylla they have fallen into Charybdis.

As a minimum net loss is the real objective point, this can be reached only by a careful adjustment of these conflicting losses. Thus, with a given furnace reducing 12 tons per 24 hours with a residue-loss of 0.5 per cent., and a chimney-loss of 10 per cent. of the ore content, it would evidently be better to treat 24 tons per 24 hours with a residue-loss of 1 per cent. and a chimney-loss of 6 per cent. of the ore content. For in the first case, the losses would net 10.5 per cent., and in the latter, 7 per cent. Such adjustments are, however, only possible where the ores and residues are systematically sampled and assayed.

## Postscript.

In my paper on "Quicksilver Reduction at New Almaden," *Transactions*, Vol. XIII., in the footnote on page 578, there is an

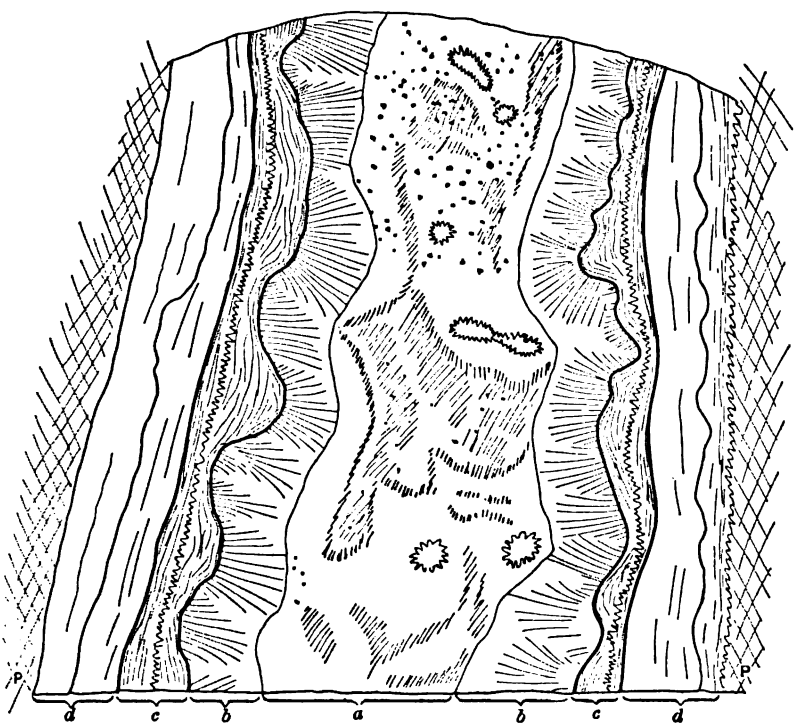
error which I desire to correct. The connecting bar of the H-piece there referred to is said to "carry" the platform with rails, etc., whereas, the platform is fixed above it; and the oscillating motion mentioned a few lines below, should be described as given to the H-piece, the following reference to apron, platform, and ore-car being omitted.

---

## *NOTE ON AN EXHIBITION OF BANDED STRUCTURE IN A GOLD VEIN.*

BY CHARLES M. ROLKER, NEW YORK CITY.

I DESIRE to put on record this memorandum and accompanying sketch of a vein examined by me, in Honduras, Central America, which exhibits a well-marked banded structure. The illustration is of natural size:




Gold-bearing Vein in Honduras, showing banded structure.

The vein traverses trachytic porphyry. It is from three to four inches wide. The central band, *a*, is of white quartz, one inch wide

it is full of cavities and vugs, lined with quartz crystals, and its mass is largely stained with the hydrated oxide of iron, in which is a heavy sprinkling of coarse gold, indicated by dots and shading in the section. On each side of *a* is a band of pure white crystalline quartz, *b*, $\frac{3}{8}$ to $\frac{1}{2}$ inch wide, showing incomplete crystals in radial forms. This band contains no gold. Next follows a band, *c*, on each side of *b*, from $\frac{3}{8}$ to $\frac{1}{2}$ inch wide. Through its centre runs a fine fissure, lined with interlocking quartz crystals, on each side of which is bluish "ribbon-quartz," containing very finely impregnated gold. The outside band, *d*, also varies from $\frac{1}{2}$ to $\frac{3}{8}$ inch in width, and is made up of compact but columnar quartz, the outside face of which (towards the wall-rock) is frequently lined with fine quartz crystals. The columnar quartz is more or less frequently stained yellow by hydrated oxide of iron, and it contains some very fine but light gold. P, P, are walls of trachytic porphyry. The whole vein-matter has a tendency to split off in slabs, in a vertical direction, the full width of the vein. The section illustrated represents, of course, an exceptionally rich piece, from one of the *bonanzas* which occur as nests and isolated, irregular bodies in the vein. From a slab, similar to the one illustrated, weighing $2\frac{1}{2}$ pounds, I panned over $1\frac{1}{4}$ ounce of gold.

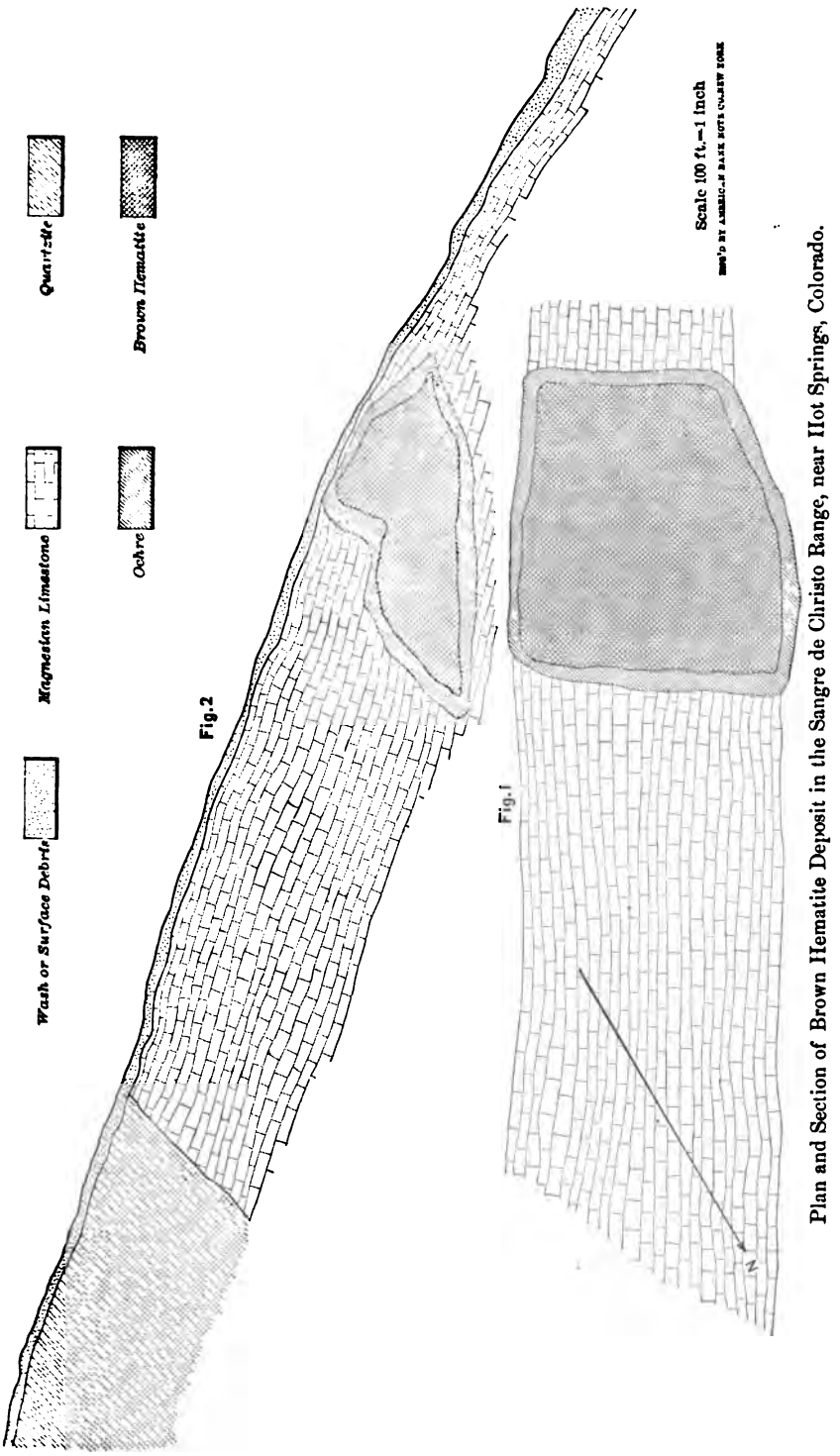
---

## *NOTES ON CERTAIN IRON-ORE DEPOSITS IN COLORADO.*

BY CHARLES M. ROLKER, NEW YORK CITY.

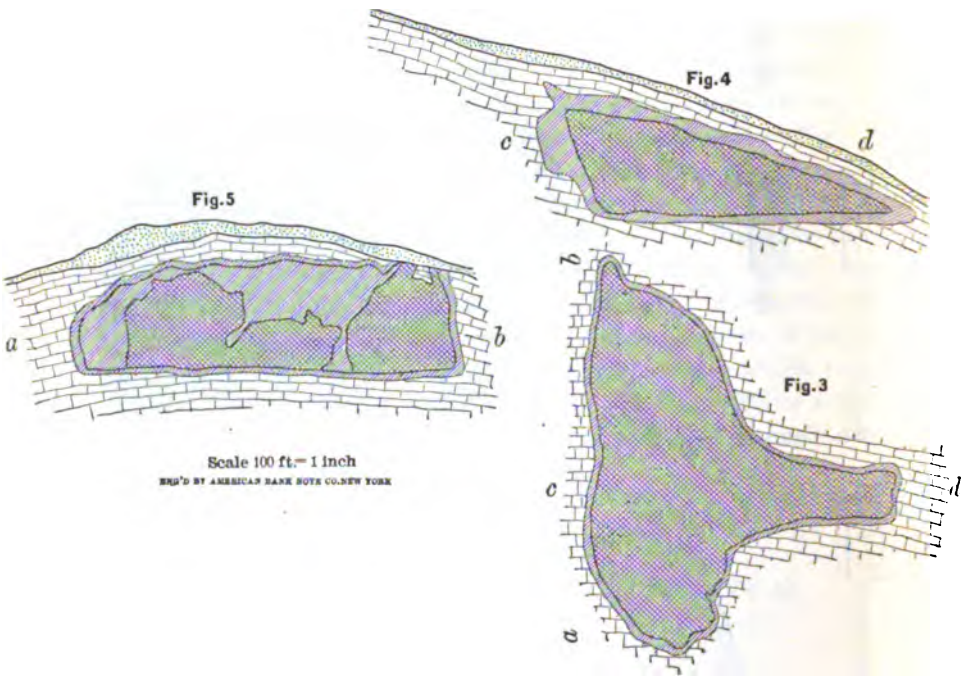
THE mining industry of Colorado received a powerful impetus from the enterprising railroad builders who, rating highly—perhaps, in some instances, too highly,—the natural resources and favorable conditions of the State for the production of the precious metals and lead, covered it, in advance of any thorough general development of these resources, with a network of railroads. At that time, everything was viewed *couleur de rose;* population was gaining rapidly, and much more in the way of productivity was expected of certain districts than was subsequently realized. It is, therefore, not quite fair to judge of the wisdom of constructing some of the branches of the Colorado railroad system from the standpoint of later experience.

With the building of railroads, a demand sprang up for iron and




Plan and Section of Brown Hematite Deposit in the Sangre de Christo Range, near Hot Springs, Colorado.

rails. Coal having been already developed, the energetic railroad builders resolved to make their own iron, and also steel rails. They created, by a consolidation of previously existing different interests, the Colorado Coal and Iron Company, which gave the first real stimulus to iron-ore mining in Colorado. It was successful in its efforts to find deposits of magnetite and hematite in the State; and




Sections of a Brown Hematite Deposit in the Sangre de Christo Range, near Hot Springs, Colorado. For explanation of markings employed, see previous page, Figs. 1 and 2.

the purpose of these notes is briefly to call attention to some of these deposits without reference to any of the other branches of industry of this enterprising corporation. If, with returning activity in the iron business, the demand for the one or the other class of ores should be increased, other deposits can be secured if wanted. I shall speak here of those only which are now under development.

*Hematites.*—Hot Springs is a mining settlement in Saguache Co. connected by seven and three-quarter miles of branch railroad with Villa Grove, which lies to the northwest of it, a distance of one hundred and twenty-seven miles from South Pueblo, at the end of the San Luis branch of the Denver and Rio Grande Railway. Hot Springs is about 9000 feet above sea level, on the west slope of the

Sangre de Christo range, in the San Luis valley, forty miles, more or less, to the west of the better-known mining town of Silver Cliff. Magnesian limestones of Silurian age are found about Hot Springs, overlain by quartzite. Alternating beds of limestone and quartzite are noticed in going up the range, until the volcanic rocks are encountered.

The strike of the grayish-black limestone about Hot Springs varies from north to northwest, and the beds show an easterly dip. In the lower limestone bed, making the foot-hills of the range, just above the valley, irregular bodies of brown hematite are found. Their tops frequently stick out above the ground; but in some cases they are merely covered by a thin crust of débris (locally often called "slide" or "wash") from two to fifteen feet in thickness, while in others there remains an additional thin crust of the magnesian limestone, heavily stained with ochreous matter. The deposits are found mainly as incrustations upon slopes, or as irregular bodies filling pockets.

Of the accompanying illustrations, Figs. 1 and 2 represent one of these bodies and its geological relations; Fig. 1 being a horizontal, and Fig. 2, a vertical longitudinal section. Figs. 3, 4, and 5 represent another body; Fig. 3 being a horizontal section at the bottom of the body; Fig. 4, a vertical section on the line *c d* of Fig. 3; and Fig. 5, a vertical section on the line *a b* of Fig. 3, giving, as it were, an end-elevation of the body. The top of the body shown in Figs. 1 and 2 is covered in the main with "slide," through which portions of the ore protrude in places. The body shown in Figs. 3, 4, and 5 has more limestone over it; but even in this case the ore-body projects at intervals beyond the surface, although no such projection appears on the section as drawn.

A line drawn through these irregular bodies would approach the quartzite to the north; and the protruding tops of a series of the bodies would have the appearance of the outcrop of a regular ore-bed. This it was for a long time believed to be; but such is not the case.

In all these deposits the body stands on a nearly flat bottom, and either the shape is that of an irregular wedge, or the upper surface of the body is irregularly curved, curving sometimes to a sharp edge, as shown in Fig. 2.

The sides of the irregular bodies are often straight, as is indicated in Fig. 5. The end of an ore-body is generally marked by a strong line of ochre, followed within a few feet by limestone

stained with ochreous matter, which lies against the regular limestone.

In the brown hematite mass proper, varying amounts of ochre occur, ranging from 30 to 50 per cent. of the mass. The average ore is a porous brown hematite of pure character, with occasional stalactitic and mammillary forms. It works freely in the furnace, makes an admirable mixture with the magnetites, and is well suited for Bessemer pig.

The bodies had yielded, up to about a year ago, over 76,000 tons of good ore. I append some partial analyses of these ores:

| | | | | |
|---|---|---|---|---|
| Iron, | 53.37 | 57.6 | 56.6 | 57.30 |
| Silica, | 7.9 | 5 6 | 6.06 | 5.03 |
| Phosphorus, | 0.034 | 0.014 | 0.022 | 0.019 |
| Sulphur, | 0.20 | 0.005 | 0.000 | 0.006 |
| Lime, | 0.35 | | 0.000 | not det. |
| Alumina, | 0.70 | 0.74 | 0.40 | not det. |
| Magnesia, | 0.05 | 0.4 | trace | not det. |
| Manganese, | 1.05 | 1.59 | 1.65 | 1.87 |

Samples of the yellow ochre taken from three different bodies contained—

| | | | |
|---|---|---|---|
| Iron, | 26 | 30.8 | 31.7 |
| Silica, | 38.7 | 33.7 | 33.6 |

Many other hematite occurrences are known in Colorado; for example, the brown hematite bog-ores of Hall's Valley; but one of the best of Colorado's deposits is the Breece deposit on Breece Hill, at Leadville. The ore there is a mixture of red hematite and magnetite, low in silica, as may be seen from the following analyses, which were made from large average samples of different lots:

| | | | | |
|---|---|---|---|---|
| Iron, | 68.3 | 65.6 | 63.0 | 63.7 |
| Silica, | 1.18 | 2.40 | 6 68 | 4.6 |
| Phosphorus, | 0.005 | 0.018 | 0.03 | 0.003 |
| Sulphur, | 0.102 | 0.072 | | |
| Lime, | trace | trace | | |
| Magnesia, | 1.50 | 0.90 | Not determined. | |
| Alumina, | 0.6 | 0.80 | | |
| Manganese, | 0.08 | 0.13 | | |

The carbonaceous or kidney-ores occurring south of Pueblo, and used in the mixtures for foundry iron, average about 22 to 32 per cent. of iron, and 11 to 17 per cent. of siliceous matter, but they run high in phosphorus and carbonate of lime.

*Magnetites.*—Magnetites, as well as hematites, occur quite extensively in Colorado; but the questions of purity and of the cost of bringing them to market, seriously affect the value of some of the deposits of both classes alike.

In Costilla county, near Pacer Station, magnetites occur in syenite, carrying 52 per cent. iron, 12.6 silica, 0.051 per cent. phosphorus, 0.017 per cent. sulphur, 5.7 per cent. lime, 1.12 per cent. magnesia, 3.6 per cent. alumina, and 0.34 per cent. manganese, with traces of titanic acid and some copper. But the cost of mining them and of bringing them to market is too great to make them available; and the copper has proved, moreover, an undesirable ingredient.

In the same county, near Wagon Creek, magnetites occur in syenite, that are either too expensive to mine and bring to market, or else they are too impure. The syenite of that locality contains, as a component part, a large proportion of magnetic oxide of iron, amounting, according to Mr. A. G. Hanmann, M.E., to 30 per cent. He claims to have extracted that proportion with a magnet from an apparent syenite.

The much-talked-of "iron mountain" of Fremont county, at the head of Pine Gulch, in the Wet Mountains, twenty-two miles from Silver Cliff, and known as the Grape Creek deposit, is made up of a series of lenticular bodies of magnetite, apparently of little depth, since they wedge out. They occur in diorite, and contain from 13 to 15 per cent. of titanic acid; from 45 to 50 per cent. of iron, and approximately 5 per cent of silica.

Magnetite beds containing a high percentage of titanic acid, are also found near Gunnison City, in Gunnison Co., and others might be enumerated. The fault of many Colorado magnetite deposits is titanic acid and too high a percentage of silica.

In Chaffee county, on the contrary, some fine deposits of magnetite are found, notable among which are the Calumet, Hecla, and Smithville deposits. These lie between the Arkansas Valley and the Park Range, on a chain of mountains running northwest and southeast, at an elevation of 9050 feet, nineteen miles distant from Salida, or South Arkansas, which in turn is ninety-seven miles, by rail, from South Pueblo, where the Bessemer works are located. Near and at these mines, the alternating limestones and quartzites are broken through on the north by a heavy belt of syenite, which "tails" to the south into a rock-mass, the principal constituents of which are hornblende, feldspar, and small quantities of quartz, with some associated chlorite and chrysolite; the exact character of the mass,

only the microscope can reveal. The rock near the surface has suffered heavy decomposition, calcspar and magnesia-compounds having resulted from the decomposition of the hornblende. This rock appears to have broken through the quartzite, since an altered belt of that description is encountered about 100 feet into this rock-mass, which itself rests on quartzite. The southwestern end of this mass is decidedly syenitic, but the character changes to the east and northeast on entering the hill, as just described. A widening of the mass in depth takes place.

The magnetite deposit occurs in this rock-mass as a long lenticular body. At the surface outcrop, it is 33½ feet wide, and it rests on quartzite. In the deposit, at the outcrop, are two layers of waste rock, respectively 12 and 14 feet thick, and two 2-foot bands of badly mixed ore, leaving the remainder of 13½ feet as fair magnetic ore. A slip of greenish talc ½ inch to 2 inches thick, separates the deposit from the footwall along the outcrop, but this is lost in depth. The hanging, or roof, of the body is not well marked, the ore shading gradually and imperceptibly into the country-rock. The strike of the deposit corresponds somewhat with the outline of the hill, being a trifle west of north, changing to north and later to northeast. The dip varies from 35° to 43° to the east. The ore in the deposit varies from a compact, granular, and crystalline, to a soft, pulverulent condition. In its upper regions, somewhat silicious, it shows in its south end, a very heavy admixture of iron pyrites. In depth the waste rock shown in the deposit in its upper portions, cuts out. At 165 feet down, along a dip of 43°, the deposit bulges out to 45 feet vertical thickness, the entire mass being a mixture of crystalline and pulverulent ore. In the next 125 feet, along the dip of the deposit, it contracts again to 15 feet, and the ore appears badly mixed with rock, and presents a fine granular character. At this depth the body appears decidedly irregular, its south end is full of iron pyrites. It had been followed about a year ago, for 210 feet in a north and south direction at this depth. In the swell of the deposit the body had been opened for 420 feet, horizontally. There, the last 60 feet, at the south end, were heavily impregnated with iron pyrites, while the remaining 320 feet were magnetite of fine quality. The north end showed indications of contracting and a steepening of dip, on the bulging footwall, throwing the body in consequence to the west of the lowest mine-workings. To judge by pit-workings and needle-indications, the body will continue northerly for 100 to 200 feet more, but with a

more northeasterly course. At 88 feet, horizontal measurement from the footwall to the east, up the hill, is noticed the outcrop of another body of 6 to 8 feet, of a mixture of magnetite and red hematite. This body was traced in the mine from the foot of the incline, a vertical depth of 207 feet below its mouth, by means of a bore-hole, and seemed to have taken a little flatter dip than the main deposit. To judge by needle-indications, the main extension of this body lies to the south, beyond the ravine running over those portions of the first body which are contaminated by iron pyrites. The needle here stands nearly vertical, while to the north of the ravine, it reads 20 to 25 degrees. This would indicate the probable lying of the bodies *en echelon*. Analysis of the outcrop, mixed ore, showed it to contain—

| | | | | | |
|---|---|---|---|---|---|
| Iron, . . . . | 32 | 45.7 | 41.8 | 48 | 42 |
| Silica, . . . . | 37 | 30.6 | 38.3 | 30.2 | 38 |

Of the subjoined analyses, I. is an average from a large lot of raw ore; II., an average from large lots of pulverulent ore, also raw; III., an average sample of roasted ore from a very large pile. These analyses, like other iron ore analyses here quoted, were made by the chemist of the Colorado Coal and Iron Company.

| | I. | II. | III. |
|---|---|---|---|
| Iron, . . . . | 51.3 | 59 6 | 50.44 |
| Silica, . . . . | 12.4 | 7.1 | 14.97 |
| Sulphur, . . . | 1.42 | 1.26 | 0.75 |
| Phosphorus, . . . | —— | —— | —— |
| Lime, . . . . | Not determined. | | 5.41 |
| Alumina, . . . | | | 3.24 |
| Magnesia, . . . | | | 4.09 |
| Copper, . . . | | | 0.017 |
| Manganese, . . . | | | 0.22 |

## *NOTES ON THE LEADVILLE ORE-DEPOSITS.*

BY CHARLES M. ROLKER, NEW YORK CITY.

IT is not my purpose to present a complete description, still less a thorough discussion from a theoretical stand-point, of the Leadville ore-deposits. Hence I have given to this paper the more modest name of "Notes;" since it is little more than a record of observations made three or four years ago, and now published from my original memoranda, with the view of preserving the facts rather than of

drawing conclusions or framing a systematic and comprehensive explanation. I shall direct attention chiefly to the westerly portion of Fryer Hill, because, in the conduct of mining operations in that locality for the Chrysolite Silver Mining Company, I became more intimately acquainted with that ground than with any other part of the Leadville region. It seems to me that, while engineers in charge of mines may not be the best qualified to discuss large questions in geology, and while they may exaggerate the importance of purely local phenomena, yet they are pre-eminently the best authority for the facts themselves, since their daily examinations give them a thorough familiarity with the details which a few visits only can not give to a stranger, who inevitably judges the underground exposures by the way they looked on the day he happened to call.

On the other hand, most superintendents lack the time, even when they possess the ability and the taste, for putting into connected form the mass of observations, written and unwritten, which guide them in their own opinions and administration, constituting, as it were, a sort of local science of ore-deposits, which would form a valuable contribution to the general science, if it could be preserved. Some, again, have a false modesty in the matter. They do not feel like stating a multitude of facts which they cannot explain; and on the field of explanation they do not dare to trust themselves. Yet nothing is more generally declared by all authorities in this science than the great importance and need of monographs, presenting simply the objective view of observed facts in single localities. Realizing this truth, I here put on record, in a form more fragmentary and imperfect than I would be glad to give them, had I the necessary leisure, the results of my personal experience.

Mine-superintendents may render, it seems to me, another most important service, by calling attention to phenomena apparently inconsistent with the generalizations of geologists. A man practically limited to the daily study of one mine for many months together, is certainly not qualified thereby to get up a theory to account for the phenomena of other mines, which he has not studied. But when some one else, with wider, but more superficial, observation, has made an induction, and propounded a hypothesis to account for the facts, then the close student of a limited area may prove a useful critic, by producing facts which militate against the hypothesis. This is perhaps a humbler function; but it is not without its value.

The geology of Leadville has been carefully studied and described

by Mr. S. F. Emmons, U. S. Geologist, and his assistants, who have made free use of the underground exposures in the several mines, and have discussed with much ingenuity and candor the large mass of facts, either observed by themselves or developed in mining operations. In the preliminary abstract of his report, which is all that has thus far appeared, Mr. Emmons describes the sedimentary beds of Leadville as Palæozoic rocks, resting on Archean masses. He further observes that during secondary times there occurred an intrusion of eruptive rocks, which spread themselves out in sheets between the strata, forming an integral part of the sedimentary formation. After the eruption and consolidation of these masses of igneous rocks there were movements producing anticlinal folds, and, when the limits of elasticity were reached, fracture of the beds and faulting.

Mr. Emmons also finds that the ore-deposits of Leadville and vicinity were deposited, not later than the Cretaceous epoch, from aqueous solutions coming from above, which derived their metallic contents from the neighboring eruptive rocks.

I summarize the above statements, by way of introduction to these notes. Others must judge, independently, to what extent the facts I shall cite will strengthen or disprove Mr. Emmons's theory of the origin of the deposits.

*General Features.*—The mines producing carbonate-ores in Leadville are mainly of three groups: the Iron Hill mines, the Carbonate Hill mines and the Fryer Hill mines. Each group has its respective tributaries; and they are divided, the one from the other, by a series of faults, carefully described by Mr. Emmons, in his abstract-report. The ores of the three groups of mines come, as admitted by all, from the same source originally; their ore-occurrence is similar, often identical. A description of one group serves as a type for all, barring local modifications.

Fryer Hill is bounded on the north by Evans Gulch, on the south by Stray Horse Gulch, on the east by Yankee Hill, and on the west by the town of Leadville, under the outskirts of which the slopes of the hill gradually disappear. The top of Fryer Hill, about 175 feet in altitude above the town, forms, approximately, the crest of an anticlinal fold. In a westerly direction this fold is followed, by a more or less undulating syncline and a subsequent short anticline. The crest of the latter anticlinal fold lies near the junction of the Kit Karson, Little Eva and Pandora claims, on west Fryer Hill. Its top has been scored off and its westerly slopes form the sides of

an apparently larger synclinal basin, over which the town of Leadville stands to-day. To the north and south of Fryer Hill, the track of the gulch-forming agent is marked by considerable scoring-off of strata.

*Geological Formation.*—The strata exposed by the mine-workings on Fryer Hill are the following, counting from below upwards. Their age has been determined by Mr. Emmons, and their thickness I measured on the westerly slope of Fryer Hill.

*Cambrian.*—Quartzite, of unexplored thickness.

*Silurian.*—Dolomite and dolomitic limestone, about 37 feet thick; Quartzite, 14 to 17 feet thick, locally called "parting quartzite."

*Carboniferous.*—Emmons's blue limestone, 45 to 60 feet thick; Felsite (quartz-porphyry), 40 to 55 feet thick; Bed of a variety of brown hematite, 20 to 50 feet (80 feet in one place in Little Chief mine); Thin cover of dolomitic sand (Emmons's blue limestone), from 0 to 40 feet thick; Felsite (quartz-porphyry), from 0 to 90 feet thick (in places scored off); Wash or drift, from 15 to 20 feet thick.

The layer of wash or drift increases in thickness towards the north, south and west, that is, towards Evans Gulch, Stray Horse Gulch, and along the slopes of the large syncline leading to the town of Leadville.

In addition to these sedimentary rocks and the felsite, a younger intrusive porphyry is observed. It appears at intervals, as if spread between the sedimentary strata, at times as breaking through them from below. These intruded sheets are sometimes locally conformable with the folding of the sedimentary strata and again appear to send up "vent-pipes", in a vertical direction, to the wash or drift. They seem on Fryer Hill to be confined to the formations above the Silurian quartzite, and they appear to split, in the horizontal plane, into branches, prong-like.

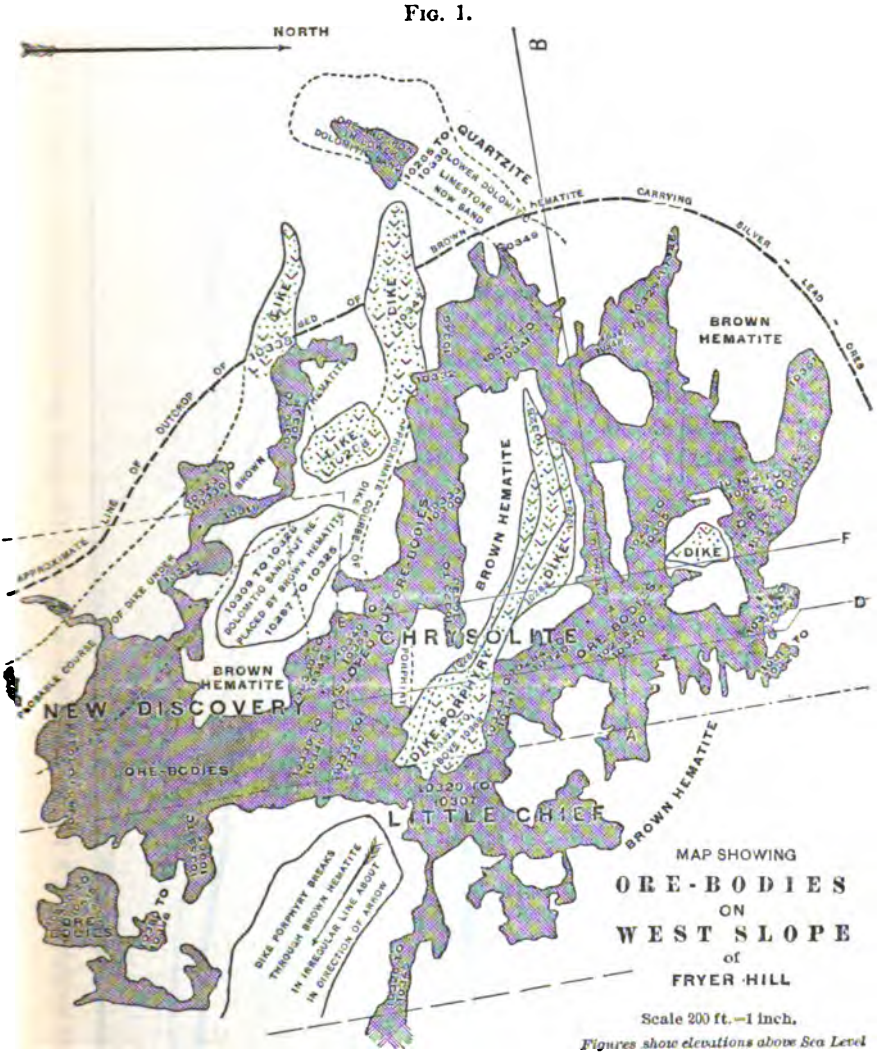
These facts, and others to be hereafter set forth, will be more clearly understood by reference to the accompanying map and sections, which I have prepared for the purpose.

The map (Fig. 1) will explain itself; it shows the form and relative position of the ore-bodies and the intrusive dike-porphyry, and the forked branches of the latter, together with its conjectural course at lower depths. The facts here represented are obtained from the workings of the Chrysolite, Little Chief, and New Discovery mines. Fig. 2, a section from east to west, on line A B of the map, through a part of the Chrysolite mine, shows the crest of the anticline of west Fryer Hill, scored off, as before mentioned, and also indicates

the characteristic subordinate foldings, which give the strata a more or less wavy appearance. The strata have a general though slight dip to the northeast.

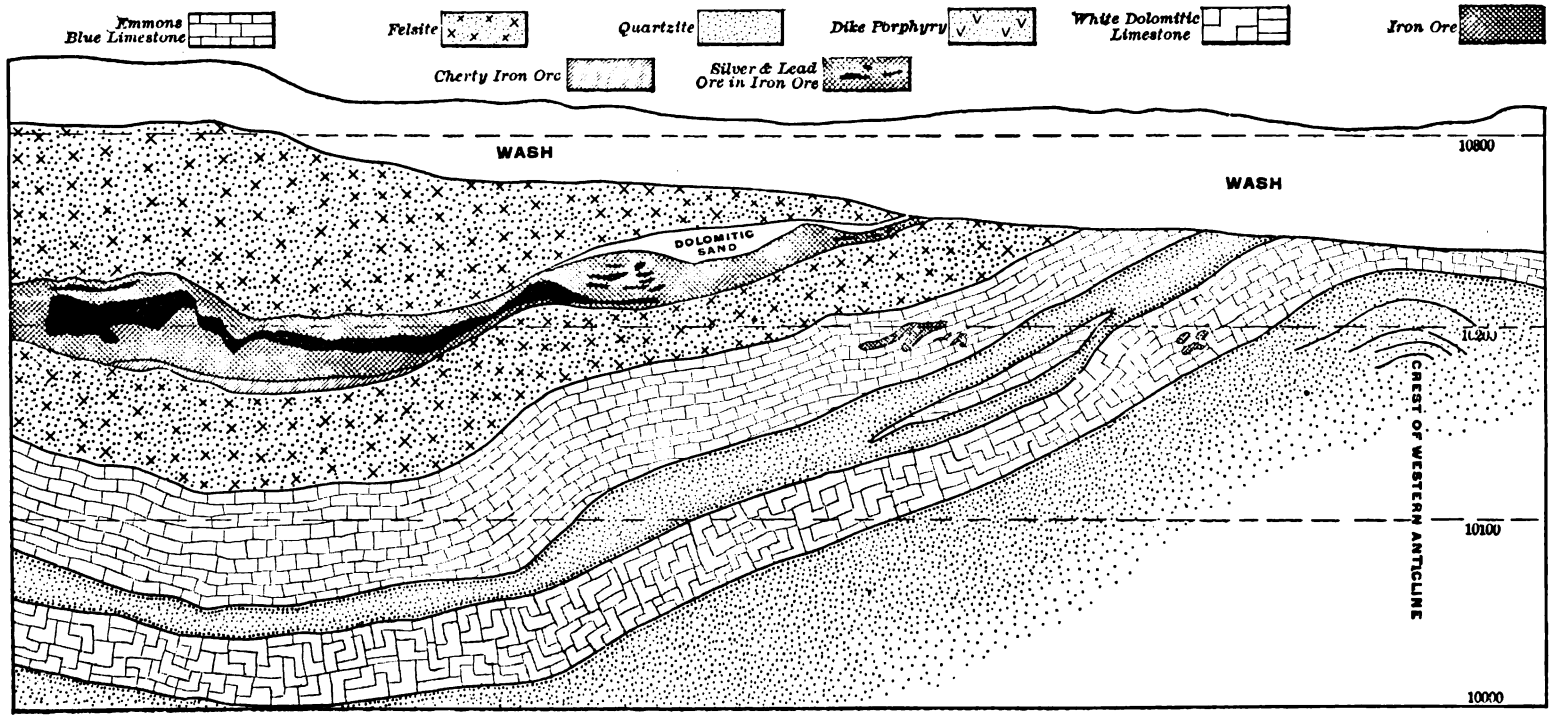
Fig. 3, a section on line C D of the map, at right angles with the section on A B, shows a vertical "vent" from the intruding

FIG. 1.



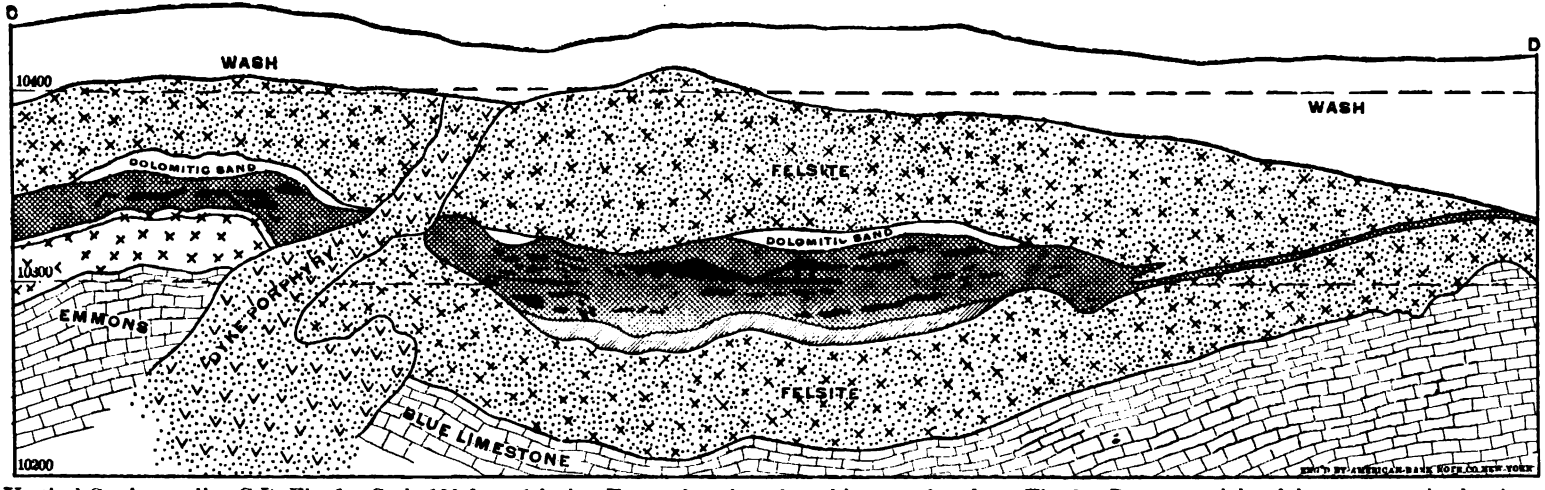

porphyry-mass, which appears in Fig. 4 on the parallel section E F, to the west of C D, as a much wider body, with two upward projections.

FIG. 2.




Vertical Section through line A B, Fig. 1. Scale 100 ft. = 1 inch. The upper quartzite is the Silurian or parting quartzite; the lower is Cambrian.

FIG. 3.




Vertical Section on line C D, Fig. 1. Scale 100 ft. = 1 inch. For explanation of markings employed, see Fig. 2. By an oversight of the engraver, the dots have been omitted, and the crosses only retained, on a portion of the felsite overlying the Emmons blue limestone, on the left of this figure.

The formation on Fryer Hill, thus hastily described, varies somewhat in its arrangement from other parts of the Leadville district, such as Carbonate and Iron Hills, but they are essentially the same. The two strata of Emmons's blue limestone, the lower separated from the upper (now mostly replaced, as will be explained, by a bed of brown hematite, with roof of dolomitic sand), by 40 to 55 feet of felsite (Emmons's white porphyry), and again overlaid by felsite, occur on the two other hills named, as one stratum of greater thickness, covered with a heavier mass of felsite, and, as a rule, with less drift or wash. I cannot account for this splitting of the blue limestone on Fryer Hill, except upon Mr. Emmons's view that the felsite (white porphyry) forced itself into the mass of the blue limestone, splitting it.

*Lithological Features.*—The felsite of the district has a felspathic ground-mass, holding free quartz granules, black and white mica. Its jointed structure is strongly marked and well preserved, and, on Fryer Hill, the felsitic mass is strongly fissured besides. Where it overlies the upper blue limestone or ore-horizon, the felsite is somewhat decomposed, but not universally so. The decomposition has not destroyed the porphyritic structure. In exceptional cases, the rock has locally suffered kaolinization; but a general softening of the felsite just above the ore-body must be admitted.

The felsite (locally named "block-porphyry"), found underneath the ore-body, separating on Fryer Hill the upper and lower blue limestone, is fairly well preserved. The felspar crystals appear distinctly to the naked eye, but their individual mass is somewhat softened. Black mica predominates largely over the white mica. The jointed structure is very well preserved, and stains of dendritic manganese are frequently observed. Both above and below the ore-body, the felsite is marked by an absence of iron pyrites. These characteristics obtain, as far as I have observed, on Fryer Hill, Yankee Hill, and Iron Hill, and from what I learn from others, on Carbonate Hill also. The character of the felsite throughout the district appears uniform. Its contents of silica vary from 68 to 75 per cent., and besides small quantities of ferric oxide, and 1 to 2 per cent. of lime, manganese, soda, and potash, the rock contains mainly alumina.

The younger, intrusive, dike-porphyry ("gray porphyry" of Emmons) appears more decomposed than the felsite. It is characterized by its mottled appearance (whence the local name, "mottled porphyry"), due to the separation of felspar crystals, which, on

Fryer Hill, often attain a length of from one-half to three-quarters of an inch. The dike-porphyry, near the ore, shows kaolinization,

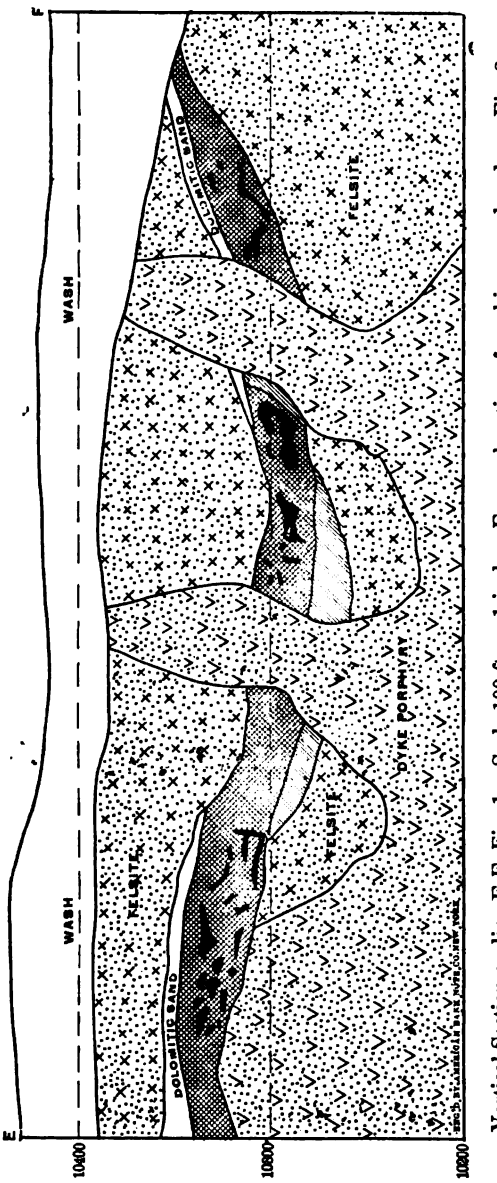



FIG. 4.

Vertical Section on line E F, Fig. 1. Scale 100 ft. = 1 inch. For explanation of markings employed, see Fig. 2.

and is colored with the hydrated ferric oxide, while, away from the ore, it appears as a more pinkish mass, having jointed structure,

and holding small crystals of felspar and granules of vitreous quartz.

Emmons's blue limestone is a dolomite. On Iron Hill, and in other parts of the Leadville district, its color is dark gray-blue, while the remnants left on Fryer Hill are lighter gray in color. Its dip is easterly, under varying angles of from 8 to 15 degrees and upwards. The bedding-planes are generally well preserved, except on Fryer Hill, where, in large masses of the rock, they have been obliterated. The blue limestone there is often decomposed to such an extent that the consistency of the rock is loosened, the formerly solid dolomite falls together as dolomitic sand when exposed, and the strata move, in contact with water, like quicksand. The quantity of silica in the blue limestone varies with its proximity to the felsite; but it can be stated to be, on an average, from 8 per cent. downwards.

The white limestone is likewise a dolomite. It has a light grayish-blue color, and carries more silica than the blue limestone. Frequently it shades gradually into the quartzites, which both underlie and overlie it. Both limestones, the blue and the white, have, on Fryer Hill, about one-quarter the thickness which they have on Iron Hill.

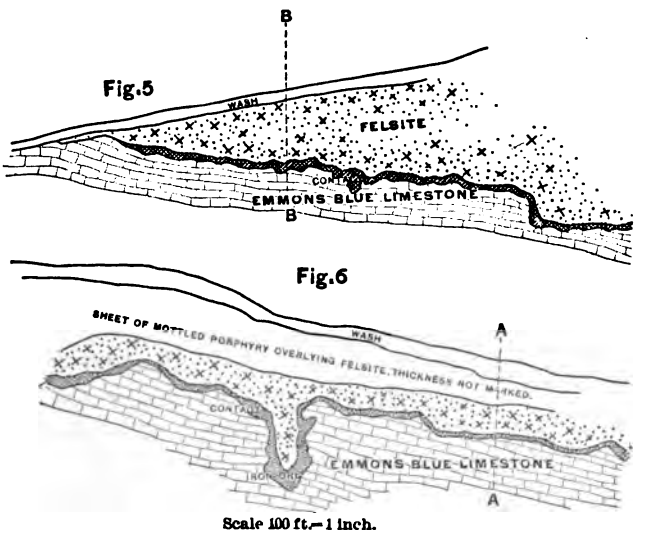
The quartzite occurring between the white and blue limestone (locally called "parting quartzite") presents no unusual characteristic features. It varies from a few feet to thirty and more in thickness; and it is rarely absent.

The thickness of the lower quartzite (Emmons's Cambrian), has not been determined on Fryer Hill. This formation is frequently stained with manganese and iron, often to so large a degree as to have caused the formation of isolated bodies of peculiar silicious brown hematite, carrying a great deal of oxide of manganese, but containing only from one to four ounces of silver per ton.

*Ore-Deposits.*—The silver-lead deposits of Leadville, commonly known as the carbonate-deposits, are the products of a substitution process, between the mineral solutions on one hand and the carboniferous limestone on the other. They are found mainly as contact-deposits, between the carboniferous limestone and the overlying felsite, with additional or incidental ore-accumulations in the limestone in irregular cavities, directly or indirectly connected with the plane of contact by irregular and often minute conduits, which a careful search reveals.

The best examples of this type occur on Iron Hill, in the Iron

mine proper, and the Silver-Wave–Silver-Cord property. In the former, the simple contact-deposit is well developed and incidental ore-accumulations are found in the lime. The Silver-Wave–Silver-Cord property shows the same contact-deposit continued on its strike, but the ore-accumulations in the Lime are heavier than in the Iron mine, probably 60 per cent. of the ore extracted having come from out of the limestone. The deposit continues on its strike for more than 3600 feet further south, through the Lime-Smuggler, Stone, Rock, and Dome claims; and the larger amount of ore in these claims has been taken from the contact-deposit. Figs. 5




Sections showing Contact Carbonate-deposit on Iron Hill.

and 6 show the position and relations of the formations here. Fig. 5 is a vertical section on the line A A, Fig. 6, at right angles with the strike of the strata; Fig. 6 is a vertical section on the line B B of Fig. 5, parallel with the strike, and coinciding with the boundary between the Lime and Smuggler claims, while the section of Fig. 5 is taken through the new south incline of the Lime, into the Smuggler claim. In these sections the dike has not been delineated, because its outlines have not been determined by mine-workings. Nevertheless, its existence there has been proved by a series of surface pits, excavated along the side line common to the two claims.

The main ore-deposits of Carbonate Hill also occur as contact-deposits between the blue limestone and the overlying felsite; but, in addition, a second and lower ore-bearing layer has been found,

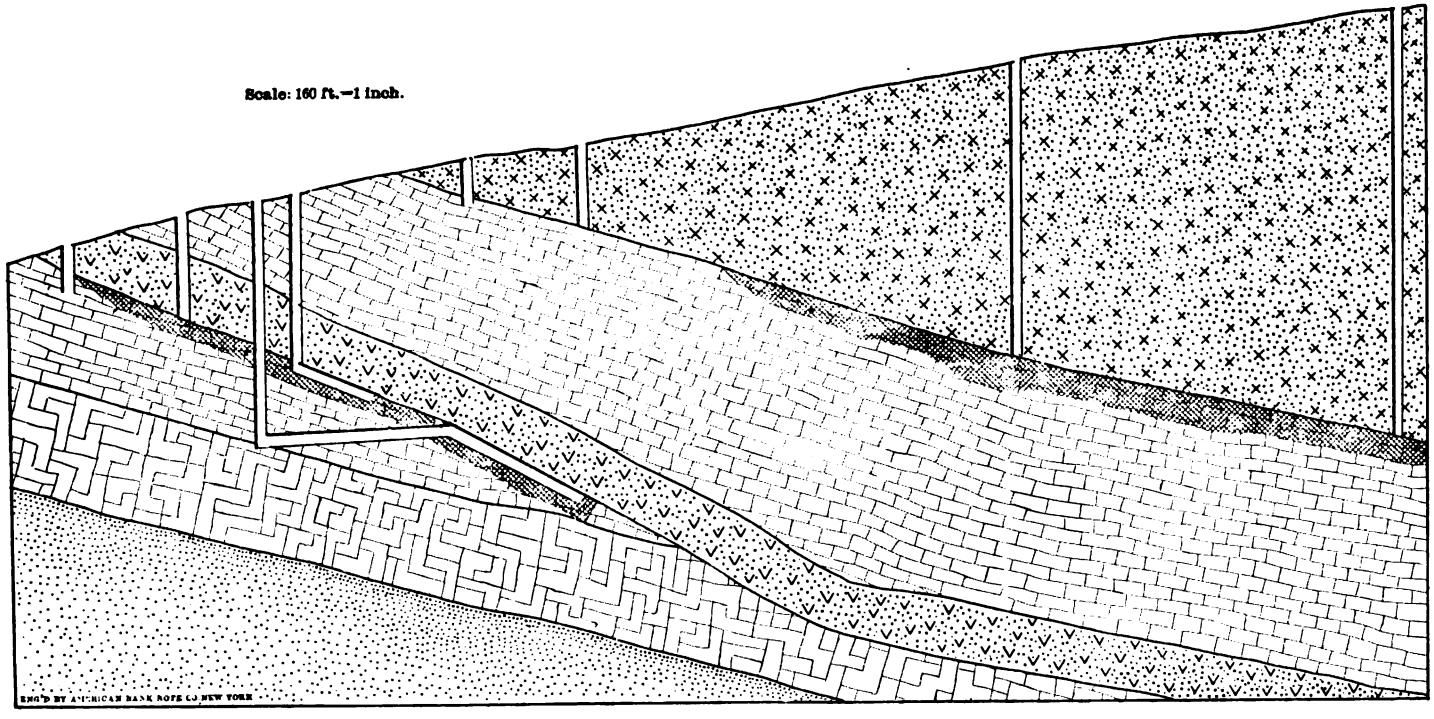
commencing in the Halfway House and Evening Star claims. It is found in the blue limestone underneath the intruded dike-porphyry (gray porphyry), which has forced itself obliquely into the blue limestone mass, considerably below the productive contact-deposit of the blue limestone and overlying felsite. The ore-occurrence in this lower layer is, evidently, different from the ordinary incidental occurrence of ore in the blue lime on Iron Hill. It has been illustrated by Mr. L. D. Ricketts, in his printed thesis for the degree of Doctor of Science, in 1883, and Fig. 7 shows the two ore-bearing layers, as represented by him in the Morning Star mine, where they are clearly distinct.

We have now to consider the peculiar conditions of ore-occurrence on Fryer Hill. As I have already remarked, Emmons's blue limestone is found on the westerly portion of Fryer Hill in two separate strata, divided by from 40 to 55 feet of felsite. The lower stratum is generally the thicker and heavier one. The ore-deposit occurs in the upper stratum, save a few local and isolated bunches which have been found in the lower. It appears that in the process of forming the mineral deposit, nearly the whole of the thin upper stratum of the former carboniferous limestone was replaced. In other words, what was once a dolomite bed is now an ore-deposit. There remains generally in the roof a very thin cover of dolomitic sand. In isolated parts of the bed no replacement has occurred; the dolomitic sand roof has remained thicker. Excepting these few islands, so to speak, of dolomitic sand, the whole of the former dolomitic bed has been replaced by mineral matter from the floor to the thin and nearly continuous cover. The map shows one of these local dolomitic sand islands left in the New Discovery ground. Another one was met in the Dunkin mine. Fig. 8 shows a local thickening of the dolomitic sand roof in the Chrysolite mine in the first north cross-drift west of the Roberts shaft.

It is a fact especially to be noted that along the floor, or in the middle, of the ore-bed, no dolomite or dolomitic sand occurs. It is also to be noted that wherever it occurs in masses, the dike-porphyry is found in immediate proximity. But the reverse is not true, that wherever the dike breaks through or is close by, there no replacement has taken place. Yet, on the other hand, the nearness of the dike seems to have influenced, in places, the thickness of the dolomitic roof left behind. The plan and sections will illustrate to some extent this observation; see Figs. 1, 2, 3, 4, and 5.

The main material or gangue of these deposits is a hydrous oxide

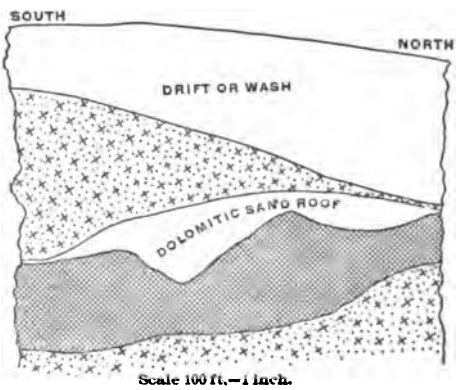
FIG. 7.




Vertical Section in Morning Star Mine. Scale 160 ft. = 1 inch. For explanation of markings employed, see Fig. 2.

of iron, carrying manganese, and calcspar and heavy spar as incidental accompanying minerals. Heavy spar only occurs locally, and to slight extent. The mass varies from a compact brown hematite to a loose, soft mixture of the oxides of iron and manganese. The compact variety is developed on a large scale on Fryer Hill, where local layers of chert are found in it, which generally underlie the ore. They are, however, by no means limited to that position only; they occur in places above the ore, and in local instances constitute the entire matrix. Chert is often found near the dike. It carries a varying amount of silica—up to 50 per cent. and more. Samples of the compact gangue of the brown hematite variety, taken

FIG. 8.




Vertical Section in Chrysolite mine, showing local thickening of dolomite sand roof.

from the Chrysolite ground, showed it to contain 8.7 to 10 per cent. silica, 32.8 to 34.5 per cent. iron, and 1.3 to 11 per cent. manganese. The silver-contents of this gangue in the Chrysolite ground varied from 4 to 8 ounces per ton. In the Little Chief and Little Pittsburgh mines, some gangue was broken which carried as much as 17 and 20 ounces of silver. The silver in this gangue occurs either as chloride or chloro-bromide of silver. There are, without doubt, large masses of this gangue in the Leadville district, which will average 8 to 10 ounces in silver per ton.

The ores found in this matrix are principally secondary products; cerussite (carbonate of lead) with the chloride and chloro-bromide of silver and a small amount of anglesite (sulphate of lead). The primary argentiferous galena, and galena studded finely and heavily with the chloride and chloro-bromide of silver, occur in larger

quantities than the sulphate of lead. Galena averaged in the regular carbonate bodies, probably, about 5 per cent. of the whole amount mined. Incidentally, pyromorphite, native silver, calamine, and other minerals have been found; and the bullion from the Silver-Wave–Silver-Cord showed appreciable quantities of gold, which were paid for by the smelters. Iron pyrites and zinc-blende had been noticed in Iron Hill ores, for example, in the Iron Silver Mining Co.'s mines; but it was after the beginning of 1882, that the sulphide ores, iron pyrites, zinc-blende, and galena, were struck in quantities, and have since then been laid open and mined in large masses in those portions of the deposit where the secondary agencies had no successful play.

The grade of the Leadville ore varies, as might be expected. The average grade of the ore from individual mines, from the same hill, generally compares fairly well, but the ore from different hills varies more largely. To illustrate, I append results from representative mines from the three hills.

| | Dry tons. | Ounces Silver. per ton. | Per cent. of Lead. |
|---|---|---|---|
| Fryer Hill: Chrysolite Mine..... | 10,561 | 65.45 | 21.45 |
| *Carbonate Hill: Evening Star..... | 6,315 | 39. | †16.1 |
| *Carbonate Hill: Morning Star..... | 4,794 | 25. | 38.45 |
| Iron Hill: Iron Silver Co. Mines..... | 152,457 | 15. | 18.6 |

Referring the percentages of lead given, to the ounces of silver, and expressing the lead in pounds, we have: *Chrysolite*, Fryer Hill, 6.5 pounds of lead per 1 ounce silver; *Evening Star*, Carbonate Hill, 8 pounds of lead per 1 ounce silver; *Morning Star*, Carbonate Hill, 32 pounds of lead per 1 ounce silver; *Iron*, Iron Hill, 26 pounds of lead per 1 ounce silver. Fryer Hill ores averaged higher in silver, per ton of ore, than either Carbonate Hill or Iron Hill ores; but the latter two contained more pounds of lead per ounce of silver.

The carbonate-ores are physically of two kinds, sand-ores and lump-ores. The lump-ores go by the name of hard ores, and include the hard carbonates of lead as well as galena. The two classes are separated by screening. In the main ore-body on Fryer Hill, the

* The data given of the Evening Star and Morning Star mines are taken from Mr. Ricketts's thesis, before mentioned.

† Mr. Ricketts mentions this yield in lead as lower than the average, from the main body of carbonate ores.

proportion of sand-ores was larger than that of lump-ores, and the sand-ores were also richer; while on parts of Iron Hill, on the contrary, the hard ores were the richer. In a lot of over 4800 tons from the Chrysolite mine, 58 per cent. was sand-ore and 42 per cent. was hard or lump-ore. Both classes of ores, taken together, averaged approximately 12 to 15 per cent. of silica, and 30 to 35 per cent. of iron and manganese. The moisture of the ore varied from 9 to 13 per cent.

The sulphuret-ores were largely developed after I left Leadville. An able and interesting account of them is given in the paper of Mr. Freeland, read at this meeting of the Institute. I append two analyses of those ores which may serve to indicate their general character:

| | I. Per cent. | II. Per cent. |
|---|---|---|
| Lead, | 15.0 | 44.0 |
| Zinc, | 24.0 | 13.0 |
| Iron, | 16 0 | 11.0 |
| Sulphur, | 40.0 | 30.0 |
| Silver, | 11 oz. per ton. | 14 oz. per ton. |

I. Analysis by Prof. Dubois of ore from the Moyer shaft, mainly a mixture of zinc-blende, galena, and iron pyrites.

II. Analysis of a 50-pound lump of ore mainly galena, from the same shaft.

Ore from the Col. Sellers mine, which I saw in large lots at the smelters, appeared, for the most part, to be a mixture of zinc-blende, iron pyrites, and galena. It was said to average, for large quantities, from 40 to 60 ounces of silver per ton.

The ore in the Leadville deposits occurs in a series of well-marked shoots, varying in width from 20 to 200 feet. On Iron and Carbonate Hills, these shoots run northeast and southwest; on Fryer Hill, nearly east and west, or, more correctly, north of west and south of east. The diagonal folding of the limestone beds into troughs and saddles appears to stand in connection with the deposition of ores in shoots, the basins being favorable to ore-accumulation.

On Fryer Hill there are two distinct ore-shoots, a northern and a southern, which fork into a third intermediate one on the west slope of the hill in the Chrysolite ground (see map, Fig. 1). The northerly shoot can be traced from the R. E. Lee mine into the south part of the Matchless and the north end of the Big Pittsburgh and Hibernia, with some interruptions into the south part of the Climax workings, and from there directly and continuously through the Amie workings, into the Little Pittsburgh, Little Chief, and Chrysolite mines, up to the southeast corner of the Little Eva claim of the latter company.

The southerly shoot passes from the Little Pittsburgh south workings, about No. 1 or No. 2 shaft, between the Little Chief No. 2 and No. 5 shafts, into the New Discovery, where the larger part of the shoot occupies the ground north of No. 2 shaft. It passes from here, via New Discovery No. 4 and Vulture No. 3, into the Vulture ground of the Chrysolite Company. This southern shoot is connected with the northern one by a northeast branch, which runs from near Little Chief No. 3 shaft, through Carboniferous No. 1 (Chrysolite Co.) and New Discovery No. 3 (Little Pittsburgh Co.), to the south shoot.

The intermediate shoot starts from this and runs through the Carboniferous and Chrysolite claims of the Chrysolite Company. It is connected with the north shoot in the triangular ground of the Eaton claim, but it remains disconnected from the south shoot, partly on account of the isolated mass of unreplaced dolomite in the northwest portion of the New Discovery, and again because of the dike separating the two in the Chrysolite Company's ground.

The western prongs of the northern and intermediate ore-shoots were found to be made up of ores of a lower grade in silver, but with a proportionately higher amount of lead per ounce of silver. In other words, part of the silver seemed to have been carried away in solution, while the lead remained in its average amount. A preponderance of hard carbonates was also noticed in the west prongs, and frequent occurrences of native silver in the northwest portions. The hydrated iron matrix in which these ores occurred, over the area indicated, was of a loose and more porous nature than that in other parts of the mineral-beds to the east.

The southern shoot, in the Vulture-Chrysolite ground, was largely composed of pure hard carbonates of lead and galena, strongly impregnated with the chloride and chloro-bromide of silver, and showing a considerable admixture of heavy spar. This small tail-end of the shoot yielded by far the richest ore. In one place, several hundred pounds of translucent chloride of silver were found in it.

The "iron" on the north side of the shoot is solid and of a dark-bluish cast, frequently carrying solitary seams or nodules of galena. In instances, in the north shoot, I have noticed in portions of the felsite, just above the regular ore-body, some galena partially changed to the sulphate and carbonate of lead, notably in the first level drift, east of the Roberts shaft. The only iron pyrites I found on Fryer Hill came from the intermediate shoot, between Chrysolite No. 1 and No. 3 shafts. It was about a hatful, of a partly amor-

phous, partly crystalline mass, surrounded by a mass of hydrous oxide of iron carrying galena. A solitary crystal I took from the felsite, near Sliver No. 2 shaft, close to the iron-body.

The ore-shoots appear separated in the mineral-bed by a line of interrupted dike, occasional vertical vents from which break well into the overlying felsite, and even to the wash or drift. These dikes, though in a general direction running parallel, do not always keep a regular course. Branches will fork off from either dike and connect with each other; or, instead of the dikes occupying the space between the ore-bodies in the mineral-bed, they will, at times, run under the ore-bodies over quite large areas. An inspection of the plan (Fig. 1) to the east of the line of outcrop delineated, will show that barren stretches (devoid of ore) occur, in the mineral-bed, in ground adjacent to that occupied by the dike-flows, and that at a little distance from the dike-porphyry circumstances were apparently more favorable for ore-deposition. The grade of the ore there was also higher than in other ground. Similar facts are observed in the other parts of the district. On Iron Hill, in the Iron Mine, the dike runs diagonally under the ore-body. The ore in one instance, in the stopes between the 6th and 8th levels, drops down into the limestone, hugging the gray or dike-porphyry closely for a distance of 50 feet or more. The ore was nearly all a gray sand-carbonate, and averaged from 55 to 65 per cent. in lead, and from 40 to 50 ounces in silver per ton—an extremely good ore for the Iron mine. In this exceptional case, good ore rested directly on the dike instead of being, as usual, a little distance from it. The mineral-bed above it (the contact) was comparatively narrow, and had a chert-roof. The gray, or dike-porphyry, on Iron Hill, occurs as it does on Fryer Hill. It is found in the blue limestone, as just mentioned; on the contact in Lime No. 1 shaft (prospect workings); in the overlying felsite, and even directly in the slide or wash in the Lime-Smuggler workings; and between the blue and white limestone on the south-west slope of Iron Hill.

According to the published report of the Iron Silver Mining Company, a shaft has been recently sunk on the fault, inside of the line of the ore-shoot, and the ore is found to continue vertically down on the fault. As I learn from others, the ore is temporarily decreasing in richness; but I think it too soon yet to assume this as the permanent character. I am told that it also contains gold.

In addition to the upper ore-horizon on Fryer Hill, a lower only partially-replaced bed of dolomite was found near Vulture No. 2

shaft, in the west workings of the Chrysolite Company. It is separated from the upper bed by felsite and gray or dike-porphyry. The strike of this bed is northeast. It was first encountered in the second level, west drift from Roberts shaft (section A B, Fig. 2), where large boulders and fragments of a manganiferous hydrated oxide of iron were found to lie in the dolomitic sand of the lower split of the Carboniferous limestone. A cross-cut was run to it from a point further west in the drift, and 32 feet above the level of the drift, and the identity of the Vulture No. 2 iron and that of the west drift was thus established. The iron-body at Vulture No. 2 shaft was irregularly triangular in form, as marked on the horizontal plan (Fig. 1) to the west of the outcrop-line. It is about 35 feet thick, in its thickest portion, and is underlain by chert and dolomite boulders. In its continuation to the east it is irregular, the dolomitic sand remaining, to a large extent, unreplaced. Under the Roberts shaft, the dolomite is almost entirely unreplaced, the iron occurring only to a very slight extent in small pieces. In this Vulture No. 2 iron, a lower ore-horizon was encountered, but of limited dimensions only. The ore-occurrence was very bunchy and irregular, in a more porous and redder hydrated oxide of iron than that in the upper ore-horizon. On an average, the ore was low in silver but proportionately rich in lead.

To the west of this body, a third mineralized zone is found in the lower quartzite, but it only assays from one to four ounces in silver, per ton. (See section on line A B, Fig. 2.)

The facts which have a bearing, in determining whether the solutions from which the ore was deposited came from above and derived their metallic contents from the neighboring eruptive rocks, may be summarized from the foregoing.

1. The overlying felsite (white porphyry) would be very much decomposed and strongly stained with the basic sulphate of iron, if metallic sulphates had been leached out of it, in any considerable quantity. This is not the case. Both on Iron and on Fryer Hill, there are areas of this felsitic porphyry nearly unaltered, overlying the present deposit.

2. If the white porphyry, overlying the present upper ore-horizon had been leached, in the course of ages, producing an upper ore-horizon, why was the underlying felsite, on Fryer Hill, not also leached, producing a second productive ore-horizon?

3. Under the same assumption, how came the hydrated oxide of iron, carrying small quantities of silver, into the quartzite under-

lying the white limestone, without any arrest of the mineral solution by the overlying dolomites and parting quartzites?

4. In case of a deposition from above, would it not be natural to suppose that the dolomite in the plane of contact with the felsite (white porphyry) would be the first replaced? Against this stands the dolomitic sand roof over our large areas, on Fryer Hill. What holds as to the origin of the Fryer Hill deposit, holds for the balance of the deposits, since they are only faulted from each other and hence belonged originally to the same bed.

5. Against Mr. Emmons's analysis of the felsite, stand other analyses which did not find any lead and silver in it (L. D. Ricketts).

Of course it might be argued that the metals had been leached out; but it would require a large number of analyses, made from many samples taken over extended areas, to establish the proposition that this rock was the source of the metals of the present deposits.

6. Mr. Emmons admits that the dikes have influenced ore-deposition as to the direction and the richness of the ore-bodies. I add to this, that so far as I have observed facts in Leadville, ore-deposition is dependent on the presence or proximity of the dike- or gray porphyry. Mining is, of course, carried on for profit and not for the sake of science. Owing to the nature of the ore-deposition in Leadville, the dikes will probably not be traced in their lower depths or in their full horizontal extent; and much must therefore remain a matter of speculation. It may never be demonstrated that the original ore-bearing solutions came up from below, and that they had a connection in time or space with dike-porphyry. On the other hand, no one can deny that percolating waters coming from above have caused secondary changes. But the proof is wanting that they originally produced the present ore-deposits; and the facts I have given seem to contradict that hypothesis.

---

## *THE UPPER MEASURE COAL-FIELD OF TENNESSEE.*

BY HENRY E. COLTON, CHATTANOOGA, TENN.

VERY little information has been published concerning the Tennessee coal-field. The State never appropriated over $600 per annum for a geological survey, and that was discontinued about 1870. Yet even with that small sum Dr. J. M. Safford made a

thorough reconnoissance, the results of which were embraced in a carefully prepared report, which is one of the most valuable contributions ever made in this country to geological literature. But the economical Legislature thought fit to publish only one thousand copies of it.

At the time Dr. Safford's explorations were made and his report was printed, coal-mining in Tennessee was very limited in area, and small in the volume of business done. Little was thought of the region northeast of Chattanooga as a factor in the future coal-trade of the State. His examinations were confined to the outer rim of the field, where, with two exceptions, no openings had been made save for neighborhood use. Later, in preparing a report on the Tennessee and Pacific Railroad, he crossed the great plateau and rapidly examined the mass of the Upper Measures on Poplar Creek. But in his *Geology of Tennessee* he only alludes to these measures at what is now Careyville, called by him Cove Creek, or Wheeler's Gap; and he speaks of them as of possibly great importance in the future. Professor J. Peter Lesley made an examination of these measures still later; but it was not intended for the public, and only a meager condensation of it has ever been published.

The Tennessee coal-field has three well-defined zones of coal-bearing strata; there may be more divisions, but with present knowledge these areas are all that can be strictly classified. One of these belongs to a horizon not usually yielding workable coals in other fields, being located below the great or Seral conglomerate. The next is immediately above that conglomerate, and extends to a massive sandstone, sometimes conglomeratic, the strata between the two boundaries being about 300 feet in thickness. In his classification of the Tennessee Coal Measures, Dr. Safford calls the series under the great conglomerate Lower, and those above it Upper, without making any line of distinction at the second or upper conglomerate, which may be assumed to be the Mahoning sandstone, and above which there are now known to be many valuable coal-seams. In a classification made by myself in a report to the State on "Coal in Tennessee," those seams below the great conglomerate are classed as Lower, those between the two as Middle, and those above the second conglomerate as Upper. This classification should be amended by dropping any regular name for those seams below the great conglomerate, since they are only of comparatively local importance. Hence, in the absence of that thorough research which alone secures accuracy, the Tennessee measures will here be classed as only Lower

and Upper, the former being the strata commencing at the great conglomerate and ending with the second conglomerate or Mahoning sandstone; and the second, or Upper, being all the strata existing above the second conglomerate. This will conform more nearly to Pennsylvania classification. My line of demarcation is based on the fact that between those two conglomerates or massive sandstones, the fossil species *Lepidodendron* is found abundantly, while I have nowhere seen it above the second. Fine specimens are to be obtained in the slates and sandstones of the Sewanee seam at Tracy City, Soddy, and Rockwood; but none have yet been found in the slates or sandstones accompanying the seam of coal worked at Poplar Creek, Coal Creek, and Careyville.

The Tennessee coal-field is peculiar in its topography. It stands up like a vast table, having on its east and west sides a low valley-region, and both sides terminating in high steep walls; but these walls are not alike either in their topography or in their geology. The length of the coal-field passes through the State diagonally, the general course being northeast and southwest. The area of coal-bearing strata is narrower to the southwest, and the northwest side of the field has a course more nearly north and south than that on the east. The boundary-line of the northwest side is a steep precipice, directly connected with the coal-bearing area, and composed of mountain limestone, shales, slates, and coals of the sub-conglomerate measures; all capped by the massive Seral conglomerate, which everywhere, on that side, makes the rim of the mountain-edge, about 1800 feet above sea-level. From its edge commence the strata which make up the Lower Coal Measures, and from its edge everywhere along the western line there is a steady dip of the strata in a line to the southeast. As this dip of the strata continues, the Lower measures sink far below water-level, and upon them are found high mountains and vast areas of strata containing coals entirely different in physical structure, as well as in chemical constituents. These are the Upper Measure coals.

The southeastern rim of the coal-field is bounded by a singular upheaval of coal-strata. This upheaval exists regularly in a line about N. 25° E., from near Dayton to Coal Creek. It is composed of the strata of the Sub-carboniferous, the conglomerate, and the Lower Measures, which in their regular dip from the northwest to the southeast have fallen deep under water-level, and have by some great convulsion been thus suddenly lifted up. This series of strata forms an outlying wall to the great area of heavy horizontal meas-

ures. Between it and the latter is a series of small streams which, running northeast or southwest, empty their waters into the Emory River, or Poplar, or White's, or Coal Creeks. These streams cut through the great wall at intervals, where are made thorough-cuts down to the valley level, and thus find their way to the Tennessee River. These thorough-cuts, or "gaps," as they are called, offer routes of extraordinary value for access to the great area of horizontal coal strata.

The area of the greatest action of this drop, or down-throw, is the locality of the Upper Measure coals in their greatest perfection, and is included in parts of the counties of Morgan, Scott, Anderson, and Campbell.

There seems, also, to have been a tilting of the strata (perhaps a mere basin-dip) from the northeast to the southwest, very gradual on the southwest side, and somewhat sharp on the northeast, at least near its beginning. This sharpness, however, may have been caused by a fault, which acts at a right angle to the great uplift of rocks just noted.

The great uplift noted is called Walden's Ridge, a name also applied, improperly, to the mountain just northwest of Chattanooga, in which the strata are nearly horizontal. Plate I, accompanying this paper, is a map showing the topography of the region. The best map for reference is the one issued by the U. S. Coast and Geodetic Survey in 1884, covering the mountain region of East Tennessee and North Carolina. The outer line of the coal-field and of the mountain range will there be seen to have a course from Chattanooga to Coal Creek of about N. 25° E. At the latter place it suddenly changes, and turns about N. 35° W., and so continues to Careyville. At that place the fault divides, or a new one commences. The course of N. 35° W. is continued in line as a fault, and with upheaved strata, for ten miles further; but the outer line of the mountain range resumes its old course, of about N. 25° E., from Careyville northward.

The N. 35° W. fault, however, cuts the coal-strata into two areas, which are entirely distinct, their coal-seams not being at all connected to the eye, though it is possible that there may be a mere jointure of the very lowest measures at some point. A section (Plate II, Fig. 1), taken four miles N. 35° W. of Careyville, will illustrate the position of the strata. In this section, the mountain limestone shows; near Buckeye Station, on the Knoxville and Ohio Railroad, it has disappeared far beneath the surface. Another sec-

tion (Plate II, Fig. 2), across Upper Elk Valley, gives an idea of the fault in its reverse course, and the great movement whereby the Upper Silurian limestone and the Clinton iron-ore are brought to the surface.

The region to the southwest of this N. 35° W. fault, and of the Knoxville and Ohio Railroad, I have named the New River coal-field, from the fact that the center of its synclinal nearly coincides with the course of a stream of that name, which empties into the South Fork of the Cumberland. The other I have named the Walnut Mountain field, from the name of the most prominent mountain range in that area. It is on the northeast of the line of the fault, and of the railroad, and is the southern prolongation of the Flat Top coal-field of Virginia. It is not my purpose here to discuss the coals of this latter field. It is almost unknown, and is now entirely inaccessible to any market.

The New River coal-field, which name I have given to the area of Upper Measure coal-seams, is included within an irregular boundary commencing at a point southwest of Wartburg, running northward, then east to near Jellico, then southeast to Coal Creek, and just inside or west of Walden's Ridge to Poplar Creek, and, just beyond there, northward to the point of beginning. It is accessible on the east to the Knoxville and Ohio Railroad, which runs south to Knoxville, and it is connected northward by the Louisville and Nashville Railroad to Louisville and Cincinnati. Its western rim is only a few miles from the line of the Cincinnati Southern Railway; and the outer part of its central portion is tapped at Poplar Creek by the Walden's Ridge Railroad, a branch from the Cincinnati Southern. Hence it will be seen that the facilities for transportation are at least fairly good.

The seams of this field have a short dip into the mountain on each side, near the Walden's Ridge and Fork Mountain faults; but their regular position has a steady rise from southeast to northwest, at the rate of about 60 feet to the mile. This is the same as the dip of the strata, heretofore indicated, from northwest to southeast. The section shown in Plate III, Fig. 1, illustrates this dip. The strata immediately on the conglomerate rim on the northwest will be seen to have fallen far below the water-level on the southeast side, and the strata accompanied by the seams of coal of the Upper Measures to have risen, so that they crop out and cease many miles before the northwest rim is reached. This is very forcibly illustrated in a seam of coal, having very distinctive characteristics, which is just

below water-level in the valley of Crooked Fork, in Morgan County, but ten miles northwest is near the top of Pilot Mountain, about six hundred feet higher than in the valley named. The fact of this primary slight drop and subsequent steady rise to the northwest is proved in the workings of the Knoxville Iron Company's Mine at Coal Creek, the largest operation in the Upper Measure strata. Their entry is 1400 yards long; the seam of coal dips for a distance of 400 yards at the rate of 55 feet. to the mile; then there is a level for 100 yards; then it rises at the rate of 30 feet to the mile to the end of the entry, 900 yards. There is also a slight dip from northeast to southwest, and there are also some local dips and slight dislocations which do not merit attention in this general description.

This basin-dip from northeast to southwest, and the reverse, is more severe on the northeast side, where the distance to the center of the basin is shorter than on the southwest. The latter dip commences near Chattanooga, perhaps some miles northeast, and obtains steadily northeastward to the New River center. For want of accurate borings or other data, it is difficult, if not impossible, to locate the position of each seam with exactness. In fact, the southwest part of the Upper Measures on Crooked Fork basin, in Morgan County, may be said to be absolutely unknown. The opposite, or northeast extreme, has been explored a little, it having been my duty and pleasure to give it a slight study in the interests of a company owning a large area of land. The examination has not yet been carried to that perfection I desired; nevertheless, much has been ascertained of a region previously almost unknown, and of the strata it contained.

To facilitate this description I shall take as a base-line on the northeast the Knoxville and Ohio Railroad, and the line of a survey from Lansing, on the Cincinnati Southern, to Poplar Creek, as a base for the southwest. The east section has no surveyed line that can be used. It is bounded by the valley at the foot of Walden's Ridge.

The elevation of the railroad at Coal Creek, mile-post 30 from Knoxville, is 938 feet; eight miles farther, at Careyville, the elevation is 1128 feet. At this point the railroad takes the course of the great Cove Creek fault. Fork Mountain is on the right, and the Cumberland water-divide, with its regular strata, is on the left. The course, as heretofore stated, is N. 35° W. Nearly eleven miles farther, at the summit, just south of the southern portal of Elk Gap

tunnel, the elevation is 1560 feet, and the top of the Gap above is 160 feet higher. On the right or northeast of the summit, the Fork Mountain fault, or fold, where Pine Mountain commences, is 700 feet higher; and the highest summit of the Cumberland, immediately on the west, is 1010 feet higher than the Gap. On the north side of the tunnel, there is a great depression and a valley more than 250 feet lower than water-level on the south side is there found. In this valley the Upper Silurian limestones and Clinton shales and iron-ores form the base, while the mountain limestone, capped by the Seral conglomerate, makes Pine Mountain, on the southeast. The mountains on the northwest rapidly fall in height and contain only the Lower Measure coals. The railroad hugs the side of Pine Mountain, and almost makes a right-angle as it leaves the tunnel, falling rapidly in its course until, at the 55th mile-post, the elevation of Careyville is reached. This valley has a general course of N. 25° E. and S. 25° W., and Pine Mountain and the Jellico Mountain (as the northwestern part of the Cumberland is here called) both conform to that course. The railroad makes a sharp turn to the east, follows close to the side of Pine Mountain, and descending rapidly at the 55th mile-post reaches the valley level, which is 1129 feet above the sea. It is thus seen that in 18 miles the railroad has risen about 430 feet and has dropped back to the same level; but this course of the railroad does not represent the strata-level or that of the surface. The great drop of the strata north of Elk Gap is distant 11 miles from Careyville, and a seam of coal there above water-level is, at Careyville, just below.

Though somewhat out of the present line of discussion, I may here state that Elk Valley has usually been thought to be a continuation of the Sequatchie Valley field. It is apparently in the same course, and may have been due to the same causes; but I have not been able to trace in the intermediate coal-field any sign of the action of the upheaval. The characteristics of the two valleys differ greatly; and the coal-field to the southeast of Pine Mountain is entirely different from that to the east of Sequatchie Valley, and that on the west of Elk Valley bears none of the characteristics of that west of Sequatchie Valley. But this may be due to the fact that in the Walnut Mountain coal-field, that southeast of Elk Valley, and also immediately west of Elk Valley, there were great downthrows, while such action was slight, east and west of Sequatchie Valley.

Plate III, Fig. 2, shows a section through Elk Gap. Practi-

cally the Upper Measure coals cease north of Elk Gap, near which point the water-divide again takes its northeast course. In the higher peaks of the Jellico Mountain range some of them may exist over small areas, but the northwest rise soon makes them disappear.

On the southwest boundary there is no constructed line of road as a guide of elevations, but enough is known from the coal-mine branch of the Walden's Ridge Railroad on Poplar Creek to show that, from an elevation of about 900 feet at that point to a locality in the Crooked Fork Valley eight miles distant, a coal-seam has risen about 350 feet. So little has been done in this Crooked Fork division of the Upper Measures, and so little is known concerning it, that sections and illustrations cannot be taken from it. Its proximity to the Cincinnati Southern Railway, coupled with the fact that routes to that great trunk-line will be all down-grade, must draw the attention of capitalists to it in the near future.

It is estimated that there are eighteen seams of coal in the Upper Measures. I am sure that there are more; but my explorations having been made to give the stockholders some idea of the value of their property, rather than for scientific research, seams of apparently small importance and those not appearing on the lands examined were neglected.

The coals of the Lower Measures do not show above water-level anywhere on the eastern sides of the Upper Measure area, except in the inclined strata of Walden's Ridge; neither do any of the smaller and lower seams of the Upper Measures. One of these is in the bottom of the creek at Coal Creek and at Poplar Creek. The first seam, therefore, which is to be noted is the seam now worked at Coal Creek, which I have assumed to be the equivalent of Coal H of the Pennsylvania series. At Coal Creek, in front of the Gap, at the Coal Creek Mining Company's and Knoxville Iron Company's Mines, this seam is about 950 feet above sea-level. There is a slight local rise to the northwest. I should have stated that between Walden's Ridge and the horizontal strata a series of creeks run from both directions, and at the water-divides of these creeks there is a rise of the strata.

At Careyville, this seam H of Coal Creek is 1140 feet above sea-level. It again appears near Buckeye Station, pitched at a steep angle, and evidently sinks under the strata to the west. It is found on the tributaries of New River, on the west of the divide. On the western side of the Walnut Mountain field, about two miles

from the Knoxville and Ohio Railroad, it is found dipping to the northeast at the rate of about one foot in twenty, and, at its outcrop, is about 1575 feet above sea-level. This change of dip, in a straight line of two miles or less from southwest to northeast, gives some idea of the great drop which has occurred on the southeast side of the fault, and the corresponding elevation of the southwest side of the Walnut Mountain field.

As previously stated, the general surface of the country rises from Careyville to Elk Gap. So, likewise, do the coal-seams; but their rise is not so great as that of the country level. A seam of coal, which outcrops on the north side of Elk Gap and is cut through in the tunnel at that point, dips southeast at the rate of one foot in twenty; but this is due to the influence of the fault which formed Elk Valley, and the dip is not maintained; for the same coal, a mile southeast, has not fallen over 60 feet.

Seam H, as I term it, of Coal Creek, is, at Careyville, 1140 feet above the sea. If maintaining a level, this seam would, therefore, be 340 feet below the horizontal measures, west of the fault at Buckeye Station; but there is every assurance that it is not so deep there; and its supposed outcroppings exist at a level on the Elk Valley side which does not indicate any such depth. The section, Plate II, Fig. 2, shows the position of the coals on the Elk Valley side and their dip, and gives some idea of the contour of the mountain. Immediately at the head of Elk Valley, the mountains are high enough to take in most of the Upper Measure coals, but, for some distance southeast, a number of the higher seams are cut out, until nearing Careyville, the whole mountain range attains its greatest elevation, and carries all the seams known to the Tennessee coal-field. The highest peak of this water-divide range I have named Mt. Safford, after the gentleman who was for so long a time the faithful geologist of the State of Tennessee. It reaches an elevation of 3400 feet above sea-level, or about 2300 feet above Careyville. It is the highest point of the Cumberland range which can be seen from the railroad, and, if I am correct in my classification, it contains, from the seam below water-level at Careyville to its top, Upper Measures fully 2400 feet in thickness. In this area, I have determined eight seams of coal, having a thickness of three feet and over, and I am sure that others exist above. At Coal Creek, Professor Bradley estimated seven seams, over two and a half feet in thickness; but there are a number the thickness of which he did not determine. Also, he has two seams, ten feet apart, of which he gives to the lower two and a

half feet, and to the upper three feet thickness. The seams which I have found, and identify as the same, are twenty feet apart, and the lower is five feet thick, the upper three and a half feet.

From Careyville up to the top of Mt. Safford, I form a section as follows:

No. 2.—Coal H outcrops, west of the fault, at about the railroad level, and within 200 yards of the track. Below, it is a mass of shales, with a large quantity of slate and nodular clay-iron-stone. The floor of this coal is two feet of slaty cannel in blocks, containing numerous impressions of *Stigmaria*. The seam dips rapidly for a short distance, and then comes to a level. The coal is of excellent quality. It was worked for some time, and then abandoned on account of the numerous disturbances of the seam. Farther away from the great fault, it would undoubtedly be regular. Thickness, four to four and a half feet.

No. 3.—Coal I, about thirty feet above, is only from one and a half to two feet thick, but yields an excellent coal. Above is a heavy mass of sandstones, forming the picturesque cliffs to be seen from the railroad station at Careyville. In them there is a coal-seam.

No. 4.—Coal J is only a few feet above the cliff, and about 375 to 380 feet above seam H. Where opened, it is a cannel coal of great excellence. About two to two and a half feet thick.

No. 5.—Coal K is immediately at the base of a heavy cliff of sandstones. This seam was opened at Careyville, and a great deal of money was unwisely expended in working it. It is from three and a half to four feet thick, and has a band of sandstone in the middle, which, while sometimes becoming thinner, never leaves it, throughout the exposure made by an entry 1200 feet long. This seam is 480 feet above H. Above is a cliff of sandstones, and still higher are shales.

No. 6.—Coal L, the next seam noted, is just above a heavy cliff, about 300 feet above No. 5, and hence about 800 feet above H. It was opened by me at several points, yields an excellent and rich bituminous coal, mining out in long, board-like pieces, and burning freely to a small quantity of ash. It is thirty-four inches thick near the outcrop. The floor is hard fire-clay, and the roof black slate, so far as developments have shown.

Above this coal is an interval of shales, in which are no massive sandstones. This interval is 300 to 350 feet thick. In it are:

No. 7.—Coal M, four and a half to five feet thick, and twenty feet above,

No. 8.—Coal N, three and a half feet thick, and 100 feet above,

No. 9.—Coal O, three feet thick. Then 100 feet higher, just below a cliff of sandstone, in layers, is

No. 10. Coal P.—This coal is from five to six feet thick. It has a floor of slate, two or three inches thick, underlaid with fire-clay. The roof is a black slate. This is a rich bituminous coal, but of cubical structure. It looks as if it would make a good coke.

No. 11.—Coal Q is 130 feet above, the intermediate strata being a mass of thin sandstones. This coal is, in all, four and a half feet thick, the lower part being two and a half feet of cannel-slate, which burns readily to a white ash, and the upper part two feet of excellent bituminous coal, breaking into small cubes.

No. 12.—Coal R is seventy feet above, sandstones and slates forming the interval. It is a rich, bituminous coal, mining out in blocks, and is three and a half to four feet thick. Above is a massive sandstone cliff.

Nos. 13 and 14 have been noted by their outcrops, and some slight prospecting work.

This is an actual section up the mountain, and of coals opened, not guessed at. It has not been made by jumping to and fro over an area of ten or more miles. In this section and classification, no note has been taken of a number of coal-seams, only a few inches in thickness. Of the seams above noted, No. 1 is about 150 feet below water-level over a large part of the field; No. 2 (H) is workable above water-level at Careyville, at Coal Creek, Poplar Creek, and on Crooked Fork, but from Careyville to Elk Gap, it can only be worked by shafts. All the others are everywhere above water-level, and can be worked by horizontal entries. It will be seen from the section that there are nine seams of coal, aggregating a thickness of over thirty-five feet, and each seam of a thickness to be worked with profit. Some of these seams are high up in the mountains; but the contour of the range is such that all can be economically worked by inclines, and there is no point where advantageously located entries could not be placed within one and a half miles of the Knoxville and Ohio Railroad. As previously stated, the Crooked Fork division can only be reached by roads yet to be built.

It remains yet a question whether, in any part of this great area of coals, there exists any seam which will make a first-class coke.

It was my opinion, from its physical structure and from experiments in open fires, that Coal P, No. 10, would make such a coke. Hence, two barrels of it were sent to Prof. A. S. McCreath for analysis. The coal sent was a thorough cut from top to bottom of the seam, and no "picking" was done. It was a true sample, and really not as good as would have been mined in regular work. In one of the partings of the seam "sulphur balls" occur, and the miner, to whom the work was entrusted, did not take either these or the slate-parting out from the coal. In mining, both could easily be separated. In a note attached to his analysis, Professor McCreath states this fact. His analysis is as follows:

| | |
|---|---|
| Moisture, | 1.268 |
| Volatile hydrocarbons, | 39.023 |
| Fixed carbon, | 48.229 |
| Sulphur, | 3.205 |
| Ash, | 8.275 |
| Phosphorus, | 0.020 |
| Color of ash, pinkish-gray. | |
| Coke, per cent., | 58.350 |

The coke made contained:

| | |
|---|---|
| Carbon, | 82.656 |
| Sulphur, | 3.163 |
| Ash, | 14.181 |
| Phosphorus, | .034 |

He says: "The physical character of the coke is fair, although it may prove rather spongy, and weak for use in *large* furnaces; but chemically, it carries an excessive amount of both sulphur and ash. The sulphur exists in the coal for the most part as iron pyrites, sometimes in masses a quarter of an inch in thickness. Its general occurrence is such as to lead to the impression that it may be present in the form of a 'sulphur-binder,' near either the roof or floor of the coal-bed. Much of the coal is comparatively free from sulphur. A different sampling of the coal-bed might, therefore, result in locating the excessive amount of iron pyrites in a particular part or bench of the bed, which could be rejected in mining operations. This would not only eliminate a large portion of the sulphur but it would materially affect the percentage of ash; for, assuming all of the sulphur to be present in the form of iron pyrites, nearly one-half of the ash must consist of oxide of iron, resulting from the iron pyrites."

His remarks as to the sampling and the position of the iron pyrites are correct. For reasons of their own, the owners of the land, from which this sample was taken, have not pursued the matter farther. But it is my opinion that any coal, which will produce a good coke, must be looked for among the lower seams, the evident tendency of the coals, as they go upward, being to increase in volatile matter. Coal R, No. 12 of the section, is very rich in bituminous matter, and has not the slighest trace of sulphur. It burns up without clinker, and leaves an almost snow-white ash. It is very near a cannel coal. A seam, about 300 feet higher, slightly opened, appears to be part cannel.

The great need of the South is a coal which will make a first-class coke. So far no exploration has discovered it, and many such announcements put out with confidence and great expectations have come to nothing. So far as Tennessee is to be taken into account, such coal has not been discovered; and the only apparent possibility of producing such a result is from the seam now worked at Poplar Creek and at Coal Creek, and formerly worked at Careyville, which appears, but has not been worked, in the upper Elk Fork region, and which has been designated as seam H, assuming that it is the equivalent of the Pittsburgh seam. No coke worth noting has ever been made from this coal, except at Poplar Creek. The manufacture there was roughly conducted, and the results of its workings in an illy-constructed furnace were not properly noted; yet it is the testimony of competent judges who saw it that the article approached nearer to standard Connellsvile coke in physical structure than any coke made from any other coal yet discovered in the South.

The following are analyses of the coal from seam H, at Poplar Creek. The phosphorus was not determined in either case.

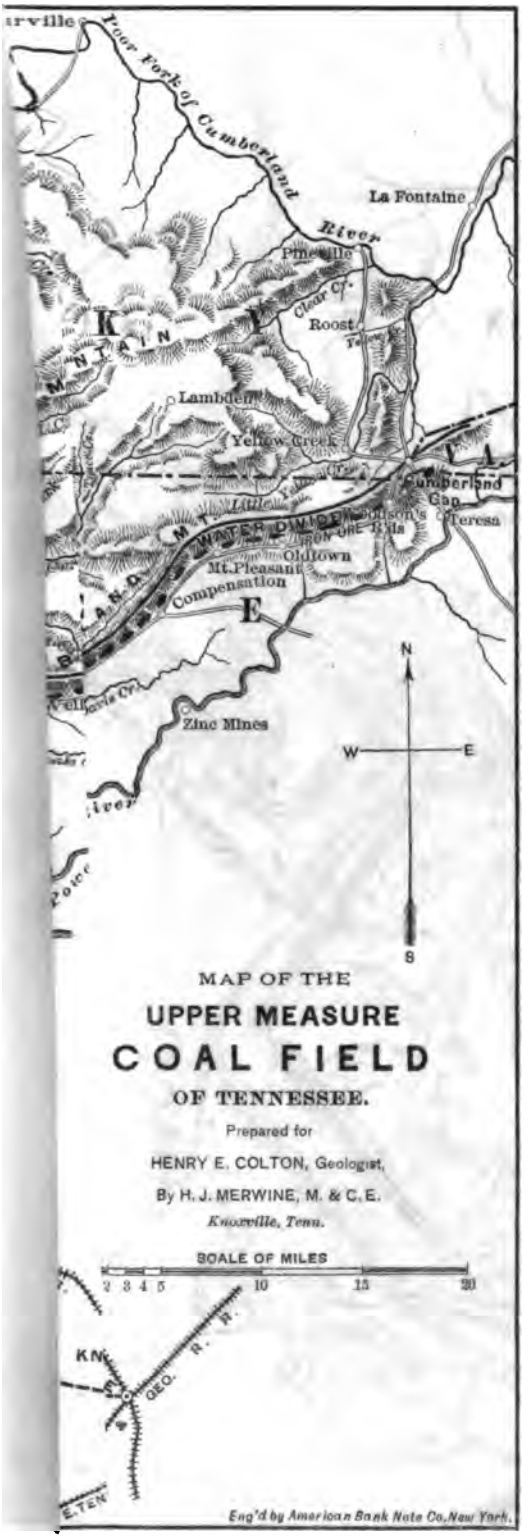
| | I. | | II. |
|---|---|---|---|
| | Coal. | Coke. | Coal. |
| Moisture, . . . . . | 1.92 | 0.27 | 1.24 |
| Volatile matter, . . . . . | 39.25 | 0.95 | 39.83 |
| Fixed carbon, . . . . . | 57.67 | 90.06 | 56.12 |
| Ash, . . . . . | 1.48 | 8.76 | 2.85 |
| Sulphur, . . . . . | 0.445 | 1.643 | —— |

I.—Chemists, Potter and Riggs, St. Louis.

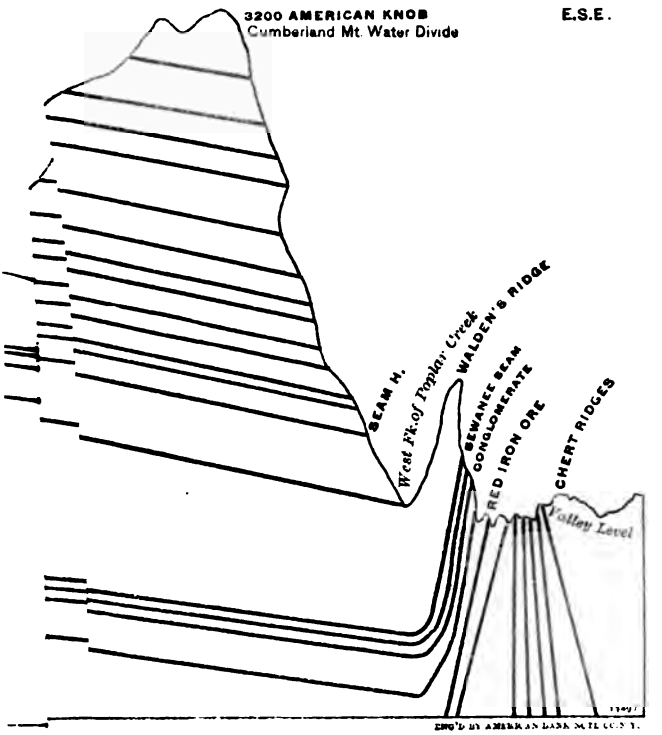
II.—Chemists, Regis Chauvenet & Brother, St. Louis. These gentlemen also report that this coal will yield 58.93 per cent. coke, containing fixed carbon, 95.24, and ash, 4.76.

This coal, like Coal P, has a proportion of volatile matter in excess of that which, it is generally assumed, should exist in coal to

# COLTON.—Plate I.



# COLTON.—Plate III.



make good coke, but that an excellent quality of coke was made from it, is a practical fact.

The Upper Measure coal-field of Tennessee, at all events, presents a series of seams, one above the other, containing a vast amount of fuel, valuable for domestic, steam and gas purposes, and so situated that it is now, and will become more and more, accessible to easy and cheap transportation. Bounded on the east and west by two great trunk lines of railroad, both of which reach Louisville and Cincinnati on the north, and the Atlantic and the Gulf on the south, the resources of this region cannot long remain unnoted by the capitalist and the careful explorer, and the wealth which I have merely sketched will, at no distant day, be fully made known.

I have endeavored to explain the peculiarities of the Tennessee coal-field: the remarkable depression of the strata from the northwest to the southeast, and the great outlying wall of rocks upheaved through that slow depression; the series of seams piled one directly over another, from beneath water-level to the top of high mountains; and the grand fault which has brought up almost amidst the coal great quantities of iron-ore and limestone. Any one of the workable seams of this coal-field would afford a large supply of fuel, but, when it is seen that there are not less than nine seams, over three feet thick, underlying thousands of acres, the amount of available fuel becomes enormous. More than 1,500,000 tons have been taken from the one seam worked at Coal Creek, yet not over 200 acres has been worked out. And above this seam there are, in the Upper Measures, at least three of equal or greater thickness. Counting them alone, if their area is assumed to be only 100,000 acres, they would afford a yield of 2,400,000,000 tons. This calculation omits all seams under four feet thick, and all of the Lower Measure seams. Yet, of the latter, the Sewanee seam underlies at least four times the area of any other seam, and has a general usefulness unsurpassed by any other.

# PROCEEDINGS

OF THE

# XLIIId (HALIFAX) MEETING.

*SEPTEMBER, 1885.*

# *PROCEEDINGS OF THE FORTY-THIRD MEETING, HALIFAX, NOVA SCOTIA, SEPTEMBER*, 1885.

## COMMITTEES.

### *Local Executive Committee.*

* G. Jamme, Esq., Londonderry Iron Works, *Chairman;* M. B. Daily, Esq., M.P., Halifax, *Vice-Chairman;* E. Gilpin, Jr., F.G.S., F.R.S.C., Inspector of Mines, Halifax, *Secretary and Treasurer;* *R. G. Leckie, Springhill; Sanford Fleming, C.B., Halifax; *T. S. Hunt, F.R.S., LL.D., Montreal; B. B. Barnhill, Joggins Mines; *J. T. Burchell, Glace Bay; *J. G. Rutherford, Stellarton; *H. A. DeCamp, Yarmouth; *J. E. Hardman, Oldham; *J. S. McLennan, Sydney; Professor George Lawson, Ph.D., Halifax.

Those marked * are members of the Institute.

### *General Committee.*

Sir Adams G. Archibald, K.C.M.G., *Chairman;* the Honorable Provincial Secretary; members of the Executive Council; members of the Legislative Council and Assembly; Nova Scotia members of the Dominion Senate and House of Commons; members of the Coal Managers' Associations of Pictou and Cape Breton; the Wardens of Cape Breton, Pictou, Cumberland, and Hants; United States Consul Phelan, Major-General Laurie, Messrs. J. S. Maclean, S. H. Holmes, Charles Annand, D. McPherson, Professor Lawson, E. Gilpin, Jr., Professor Fraser, P. Innes, E. W. Dimock (Windsor), A. A. Hayward (Renfrew), J. W. Carmichael (New Glasgow), Graham Fraser (New Glasgow), W. G. Matheson (New Glasgow), G. Jamme (Londonderry), J. W. McDonald (Londonderry), D. McGillivray (Sydney), J. E. Burchell (Sydney), S. MacDonnell (Port Hood), C. E. Brown (Yarmouth), P. McNaughton (Joggins).

### *Citizens' Committee.*

Mayor Mackintosh, *Chairman;* F. C. Sumichrast, *Secretary;* Aldermen T. Spelman, J. E. Wilson, A. Stephen, G. McLellan, H. F. Worrall; Sir William Young, Chief Justice McDonald, the Hon. Provincial Secretary, the Commissioner of Mines, Hon. J. W. Longley, the Hon. Attorney-General, Senator Power, Hon. Robert Boak, Hon. James Butler, Hon. W. J. Stairs, M. B. Daly, M.P., Professor Lawson, Principal Forrest, Dr. Parker, Rev. D. Honeyman, Rev. Dr. Burns, John Kelly, Dep. Com. of Mines, E. H. Keating, M. Murphy (Prov. Eng'r), M. Bowman, Hon. A. G. Jones, Adam Burns, John Doull, H. H. Fuller, T. E. Kenny, W. Lawson, Charles Annand, George Mitchell, W. C. Silver, J. R. Lithgow, H. W. Blackadar, S. H. Holmes, F. B. Crofton, W. Roche, Jr., J. P. Mott, James Thomson, J. J. Stewart, F. C. Elliot, Peter Jack, E. Gilpin, Jr., S. D. McDonald, Rod. Macdonald, C. A. Stayner, W. McKerron, F. C. Stevens, D. McPherson, G. Francklyn, J. E. Handman, H. W. Johnson, R. Motton, Dr. Somers, W. Gossip, G. J. Dustan.

### *Sub-Committees.*

*Finance Committee.*—J. F. Stairs, M.P., *Chairman;* Brooks Chipman, Hon. W. Ross, W. L. Lowell, J. S. Maclean, S. M. Brookfield, C. A. Stayner.

*Reception Committee.*—M. J. Power, M.P.P., *Chairman;* Professor McGregor, Colonel Ackers, R.E., M. P. Daly, M.P., Sheriff Archibald, Alderman McInnes, Hon. J. W. Longley, M.P.P.

*Dinner Committee.*—T. E. Kenny, *Chairman;* S. H. Holmes, Alderman Pearson, H. H. Fuller, E. Farrell, M.D., A. Burns, John Doull, L. G. Power, Alderman McInnes.

Headquarters were at the Halifax Hotel.

The first session was held on Wednesday, September 16th, at 10 A.M., in the hall of the Council, Province Building.

The meeting was called to order by Mr. G. Jamme, chairman of the local Executive Committee, who briefly welcomed the Institute to Halifax, in the name of the resident members. At the close of his remarks, Mr. Jamme introduced Sir Adams G. Archibald, chairman of the General Committee, who spoke as follows:

*Gentlemen of the American Institute of Mining Engineers:* I consider myself very fortunate in having the privilege of bidding you welcome to the Province, a privilege incident to my position as chairman of the provincial committee appointed in reference to your reception. I avail myself of this privilege, and now, on behalf of the whole people of Nova Scotia, tender you a cordial welcome.

We are greatly gratified that the Institute should have done us the honor to appoint a meeting in this Province, and we are delighted to see so many of its members present on this occasion.

We welcome you on various grounds. If you had come on the visit merely as citizens of a friendly country we should have been delighted to see you. You are connected with us by many ties, the ties of a common lineage and a common language, a common literature and common traditions. You are sharers with us and the parent country in common political and judicial institutions, and in a fulness of freedom such as exists nowhere else in the world. Had you come, therefore, with these claims only on us, we should have been delighted with the opportunity of showing the gratification your visit would confer. You come, indeed, with all these claims on our regard, but you have others still. We welcome you on these grounds, but we welcome you also, some of you as representatives of great industries in your own country, others as men of special skill and science, who have made your names household words everywhere. All of you we welcome as connected with a profession which has done more, perhaps, than any other to promote improvements in the material condition of the world.

It has been the task of that profession to grope in the bowels of the earth for the treasures that nature has hidden there: to clear them from the dross with which they are associated, to purify and prepare them for the use and comfort of man. You have had to organize inert matter, to put it into shapes and forms by which it could be utilized—so as first to create, and then to direct, a motive power—and thus making matter the slave of mind, to perform prodigies of power and endurance and speed which have revolutionized the world. We welcome you, therefore, as gentlemen connected with this great profession.

But besides all this, we have an *arrière pensée* not quite unselfish. We know that your visit will give us pleasure. May we be pardoned for entertaining the idea that it may also profit us in the result?

We claim in this Province to be possessed of large mineral treasures. I do not refer to the gold and the silver, the royal minerals, because whether we have them or not is a matter of comparatively small importance to our country. But as regards those minerals which everywhere form the basis of national prosperity, those which are of absolute necessity and universal use—iron and coal—these we have unquestionably in great abundance and of excellent quality. But there are other minerals scattered over the length and breadth of the Province; not, indeed, of such commanding interest, but valuable enough to form important elements in our future prosperity. Of some of these you will soon, I trust, have an opportunity of judging from personal inspection, and it will give us great pleasure to facilitate your movements in any direction in the line of your inquiries.

Perhaps it might not be out of place to give you, or those of you whose researches may not have been directed in this way, some general idea of the position in which our mines and minerals stand, how property in them can be acquired, and by what title it is held.

I do not propose to enter largely into the question. The story is a long one. But it need not all be told. All that is required can be said in a few words. The story is worth a passing notice, if only to remind our people of the great gulf there is between the ideas of colonial government which obtained in England as late as sixty years ago, and those which prevail now; if only to show how utterly dead and buried, how deservedly dead and buried, are the old ideas of dealing with outlying provinces. Of course, a transaction of the kind I am about to glance at could not occur in our altered political

condition, but with the ideas of the present age it would be equally impossible even if our condition had remained unchanged. At this moment we have as entire a control over our local affairs as if the Dominion were a republic and the governor-general its president.

First, then, a word or two of history. You are all sufficiently familiar with the history of England at the beginning of this century to know that good old George III. had not a very reputable family of sons. He was himself the most frugal, the most honest and the most conscientious of sovereigns, even if the most obstinate and self-willed. Yet, notwithstanding his frugality, he wasted millions on millions on war. His obstinacy cost England the thirteen States which formed the nucleus of your great country. His narrow and rigid treatment of his sons in endeavoring to bring them up religiously, to train them to habits of prudence and economy, to fit them for the high positions they might be called to fill, inspired though it was by the conscientious desire to do his duty as a sovereign and a father, only drove them into antagonism to himself—into dissipation, extravagance, and embarrassment. It made them spendthrifts, one and all. At last, the good old man was gathered to his fathers, and his son George reigned in his stead. The new sovereign, while Prince of Wales, was habitually over head and ears in debt. Time and again the nation had stepped in and relieved him. But parliament very naturally was willing to do for the heir-apparent more than for the other brothers. Among these, perhaps, the most extravagant was the Duke of York. He had managed to incur a frightful amount of debt. His creditors, after waiting long, became impatient, and, when George IV. had been some six years on the throne, menacing. It was during the premiership of the Earl of Liverpool, towards the close of the long administration of which that nobleman was the head. The creditors applied to the earl. The duke was sick, the creditors pressing—what was to be done? The minister dared not go to parliament. He had been there too often before on similar errands. The sovereign himself was not anxious to have the application made. He had had enough difficulty of his own. He had no mind for the renewal of unpleasant discussions. Then a notable scheme was devised. The creditors of the duke saw that he was dying. If anything was to be done, it must be done quickly. If it could not be done at the expense of England, why not do it at the expense of some far-away province? The rights of the duke's creditors, of the men who had sold to him and his household wines and

diamonds and groceries at extortionate prices, were sacred. What mattered it about the rights of a people far off beyond the great ocean? Accordingly, the sovereign was advised to pay the duke's wine-merchants and jewellers and grocers by a grant to him, which he might sell them, of all the mines and minerals of the province of Nova Scotia. The advice was acted upon, not any too soon. The grant, passed on the 26th August, 1826, was transferred to the creditors on the 12th September, and within four months thereafter the duke was in his grave.

By this stroke of business, the duke's creditors realized $600,000. By it the whole of our mines and minerals were disposed of in one fell swoop; not the royal metals only, the gold and the silver; not the important minerals only, such as iron, copper, coal, lead and tin; but everything that was in the soil except the soil itself. The lime-stone, slate-stone, slate-rock, gypsum, and even the clay itself, became, from that moment, the property of the gentlemen who had suggested to the sovereign this "new way of paying old debts."

But there was a question how far the grant extended. It purported to convey the mines of Nova Scotia; but what did the words "Nova Scotia" mean? Cape Breton had been for forty years or thereabouts a separate province. In 1820 it was annexed to Nova Scotia. It was unquestionably a part of Nova Scotia for purposes of government, but was it so when it was a question not of government but of local description? The crown officers were appealed to, and they decided that the grant did not extend to Cape Breton. What then? The General Mining Association were at headquarters. They had ready access to the colonial office; and another brother of the Duke of York, who had ascended the throne in the meantime, was advised to extend the lease by including the mines of Cape Breton in express words.

For thirty years the mining question was a battle-ground. The combatants were the Legislature of Nova Scotia, the General Mining Association and the Colonial Office. The lease was for sixty years, and half its term had expired before the slightest approximation to an arrangement was made. At length, in 1857, the House of Assembly sent two delegates to England to see what could be done. They went over, spent several months in negotiating an arrangement, and finally returned with a provisional agreement they had made, subject only to the approval of the Legislature. The agreement was duly submitted to that body and ratified, and thenceforth the mining question was at rest.

By the arrangement so concluded, the Association gave up all claim to any minerals included in their lease, except only coal, and they gave up all the coal except what was within certain defined limits, of small extent, but large enough to last them much longer than their term. Then the Legislature stepped in, and by statute vested in the owners of lands all the baser minerals, all indeed except gold and silver, lead, copper and coal, tin and precious stones. Whoever, therefore, now owns, or shall hereafter own, the soil in any part of Nova Scotia, owns also all the minerals except those just named, which belong to the crown, or rather to the Province, for whose benefit they are reserved. Under this agreement, mines have been opened in every part of the Province. There are collieries actually worked in six of the eighteen counties into which the Province is divided. Gold-mines have been opened in twelve proclaimed districts in six counties, and in other districts not proclaimed in other counties. Already, over one hundred coal-leases have passed the great seal, and the leases of gold-mines are innumerable. The royalties reserved are 10 cents a ton on coal; iron, 3 cents a ton on the ore; gold, 2 per cent., and all other minerals 5 per cent. These royalties go to form a fund for the support of the local government, which derives, in one way or another, over $100,000 a year from this source.

While the freeing of our mines from the monopoly of the Association gave an immense impulse to them, the fiscal policy which the United States have adopted, has tended to retard the development of our coal-interests. From 1854 to 1866 our coal was admitted into the United States free of duty. Before the reciprocity treaty was repealed, two-thirds of our entire sales were made to that country. After that, the States imposed a duty of $1.25 per ton. This soon reduced our exportation to that country. The trade in six years dwindled from $\frac{2}{3}$ to $\frac{1}{8}$ of our whole sales. Then the duty was reduced to 75 cents. But the trade continued to dwindle, till in 1884, instead of being $\frac{2}{3}$, it fell to $\frac{1}{20}$ of our entire sales. But in the meantime our total sales, notwithstanding the reduction in, or rather the extinction of, the sales to the United States, have gone on increasing from year to year, and last year we sold well on to 500,000 tons more than we did when our trade with the States was in the most flourishing condition. It would seem, therefore, that our coal trade is not dependent on the United States market. But when the time comes, as doubtless it will, when the laws of nature prevail, when they cease to be overridden by fiscal restrictions, and the trade

is allowed to flow in its proper natural channels, it will be found that the opening of American markets to provincial products will not only greatly extend our industries, but will add to the comfort and convenience of the large classes in the neighboring country to whom cheap fuel, cheap light and cheap mechanical power are blessings.

But I have said enough—perhaps more than enough—on the subject to which I have directed your attention. It now only remains for me to close my remarks by saying again that we extend to you the heartiest welcome in our power to give.

After the applause which greeted the address had subsided, Mr. Jamme introduced Hon. J. C. Mackintosh, Mayor of Halifax, who extended the welcome of the city, as follows:

After the eloquent and interesting address of Sir Adams G. Archibald on the political history of the mining industry of Nova Scotia, and seeing that he has bidden you welcome to our Province and city, and thus taken that part of my pleasing duty on his own shoulders, it would be the correct thing for me merely to repeat the word "welcome."

I would, however, say a sentence or two to show our appreciation of the honor conferred on our city by the visit of the Institute. In speaking of the battles of the past for freedom to our mining industry, Sir Adams G. Archibald has not done himself justice, as the greater share of the honor is due to him for his exertions in and out of the Legislature in Nova Scotia and Great Britain, and his noble fight against the old monopoly has earned for him the gratitude of his fellow-countrymen.

Most of you have come a long way from your homes, away down East, but we trust you will enjoy your visit, and I have no doubt the result will be both beneficial and profitable to you. Some of our good friends were afraid of the disease now raging in Montreal, and though I know to talk of smallpox in the presence of Dr. Hunt is to him as unwelcome as to speak of fog to a St. John gentleman, who is also present, yet I merely mention this to say that no epidemic disease can attack Halifax. Our city is away out on the Atlantic Ocean, and is so ventilated and swept by the breezes and gales of that great ocean that no epidemic can touch us.

We have little if any sickness, and in fact, the greater number of our people die of old age. Visitors are attacked with consumption in this cool, bracing climate, but it is not a consumption of vitals, but

one which attacks hotel dinner-tables, and which is rather enjoyable than otherwise.

In looking over the book prepared by the secretary I would note just a few points on which to say a word or two. The statement that the output of the mines of the United States was last year the enormous amount of $413,000,000 is calculated to fill one with wonder, and coupled with the knowledge that hundreds of millions are invested in the mining industry, and that the lives of hundreds of thousands of miners are confided to your care and skill, it exalts our estimate of the value and importance of the Institute of Mining Engineers, which educates its members and enables them to discharge the duties of their calling with skill and ability. You speak and write of hundreds of millions in connection with your mining industry; but we are a small country, and still can speak of millions. We raised nearly 1,500,000 tons of coal, and our mines since their opening have raised 22,000,000 tons. Our gold, so far, would amount to upward of $7,000,000. Taking our population into account, our percentage last year in coal and gold is equal to that of the United States. Americans like to talk of big things. Well, Halifax has one of the biggest things in its line in the world; for Mr. Gilpin's statement of the gypsum quarries of Windsor is that they are the largest in the world. You can verify this by a couple of hours in Windsor any afternoon. We have also the finest harbor in the world, which we will prove to you this afternoon; and also one of the finest climates in the world, as witness this beautiful weather we are now enjoying.

If I savor a little of spread-eagleism, please put it down to the fact that my mother was born in Boston!

I would again, in the name of the citizens of Halifax, give you a cordial welcome.

President Bayles responded as follows:

On behalf of the American Institute of Mining Engineers, I have great pleasure in expressing the obligation of the visiting membership for the very cordial and eloquent words in which we have been welcomed to Nova Scotia.

If we came here feeling that we were strangers in a strange land, there is little probability that we shall be permitted to retain that feeling—still less that we shall desire to. Wherever the spirit of progress and development has made itself felt, there the engineer will always find himself at home. For him home has ceased to be

what Prince Metternich once said Italy had become—"a mere geographical designation." Give him something to do worthy of his skill and ambition, and, even though it be in the uttermost parts of the earth, there is home for him. I do not, of course, mean to intimate that I consider Nova Scotia one of the uttermost parts of the earth—though whether it is or not depends, obviously, upon where one fixes his geographical center.

But, whatever our assurance of a pleasant and profitable visit, we must confess that we are amid as yet unfamiliar surroundings, knowing very little of the country or its resources, and I cannot hope to frame a response to the addresses of welcome which, like them, shall be both entertaining and instructive. On behalf of the membership I can only say that we have come to learn, and that our receptivity for knowledge is unlimited. That we shall see much of professional interest we are well assured. The gold-bearing quartz veins of the great area of Cambrian rocks on the eastern slope of your peninsula do not, I believe, show any bonanzas, but I am informed that they offer satisfactory inducements for legitimate mining. Of your widely-distributed and valuable deposits of iron ore we shall probably see but little; but from Mr. Gilpin's excellent report for 1880 we may gain much exact and valuable information, especially if we are favored by a chance to see the ore-piles at Londonderry. Of your coals, those which will probably have for us the most interest are the ones possessing most good coking qualities. An impression prevails across the border, even among well-informed ironmasters of the Eastern and Middle States, that Nova Scotia produces no coking coals in quantities great enough to give them an industrial importance. On this point I find that we are misinformed. Mr. Gilpin assures me that in Cumberland County the Spring Hill mines yield a very fair coke, low in sulphur and carrying only about 12 per cent. of ash. In Pictou County the Albion and International coals yield a good firm coke with 14 to 15 per cent. of ash. In Cape Breton County there are several beds of coal from which satisfactory coke can be made with 7 to 10 per cent. of ash. Coals from the Sydney, International and Glace Bay mines are all coking coals. The best results thus far obtained in coking them could probably be much improved by a better preparation of the coal for the ovens, but my information leads me to believe that their present average is better than the average of Alabama and Tennessee cokes. When we consider how much cheap coke is needed in New England and the Middle States, and what possibili-

ties of cheap iron and steel production they suggest, even a consistent advocate of high protective duties might be so far forgetful of his principles as to wonder whether the free importation of Nova Scotia coke might not be advantageous. My friends of the Institute will excuse me if I refrain from venturing any views of my own on this point, but if cheap coke from here, suitable for use as metallurgical fuel, and bearing only the charges of shipment in bulk by water, could meet on equal terms the cheap carbonates and magnetites of the Hudson and Champlain valleys, almost any one of us would willingly contract to make pig iron at any eligible point between Sandy Hook and Troy at as low a cost per ton as it can be delivered there from any competing center of production—domestic or foreign, near or remote.

Considering the relations which for some years have existed between the United States and British America, each intrenched behind *chevaux-de-frise* of protective duties, it must be admitted that they are not such as to furnish much inspiration to the speaker who should be moved to trace what we have so often heard described as the "manifest destiny" of the two countries. So far as I can learn, the United States have not as yet suffered irreparable injury from the restriction of commercial relations with the Dominion, especially as the border trade has been large and profitable during most of the time; and, judging from appearances, I should say that the Dominion has thus far managed to get along very comfortably without reciprocity. But who shall predict the future? Last winter I saw in Montreal the wonderful ice palace which made its Carnival memorable. Skilful architects planned it, calculating its proportions and estimating its strains as carefully as if each cube of crystal was a cube of granite. Finished, it rose resplendent, as if hewn "from one entire and perfect chrysolite." But in a few weeks the warm south wind breathed upon it; the gentle rain honeycombed its towering battlements; the armies of the sun were marshalled against it; its stately *façade* was pierced with silver arrows, and it sank and disappeared like the unsubstantial fabric of a vision. And as I looked at it I thought—As with this mimic fortress, so shall it be with the barriers reared between this country and mine. When the time comes they, too, will sink and disappear. I know not whether stronger and closer ties than those of commerce will ever bind us, but I do not doubt that, together and in the harmony of mutual interests, we shall realize the prophecy which tells us how—

"Turning to our mother, England, we shall find
her making boast
Of the great Republic westward, born of strength
that she has lost;
And our Saxon blood shall join us, never to be
torn apart,
Moving onward to the future, hand in hand and
heart to heart."

Dr. T. Sterry Hunt, of Montreal, read a Note on the Apatite Region of Canada, and H. S. Poole, of Stellarton, N. S., a paper on the Pictou Coal-Field, after which the Institute listened to a description of the Glacial Phenomena of Nova Scotia and their Relations and Significance, from Rev. D. Honeyman, of Halifax.

The second session was held at the same place on Thursday afternoon, September 17th, when the following papers were read:

The Present Value of Steel Castings, by Arthur V. Abbott, New York City.

Topographical Models: their Construction and Uses, by A. E. Lehman, Philadelphia, Pa.

An Electrical Furnace for Reducing Refractory Ores, by Dr. T. Sterry Hunt, Montreal.

The Cape Breton Coal-Field, by W. Routledge, Sydney, C. B. (read by the Secretary).

The following papers were read by title:

The Amalgamation of Gold Ores, and the Loss of Gold in Chloridizing-Roasting, with Especial Reference to Roasting in a Stetefeldt Furnace, by Charles A. Stetefeldt, New York City.

Lixiviation and Amalgamation Tests, by F. W. Clark, Boston, Mass.

The Manufacture of Iron in Canada, by J. H. Bartlett, Montreal.

The Homogeneity of Open-Hearth Steel, by H. H. Campbell, Steelton, Pa.

Improvements in Ore-Crushing Machinery, by Stephen R. Krom, New York City.

Note on a Self-Dumping Water-Tank, by W. Ide Pierce, Tangier, N. S.

The Estimation of Manganese, Carbon, and Phosphorus in Iron and Steel, by Professor Byron W. Cheever, Ann Arbor, Mich.

E. D. Campbell's Colorimetric Process for Estimating Phosphorus in Iron and Steel, by Professor Byron W. Cheever, Ann Arbor, Mich.

The Product and Exhaustion of the Oil Regions of Pennsylvania and New York, by C. A. Ashburner, Philadelphia, Pa.

The Contraction of Iron under Sudden Cooling, by H. M. Howe, Boston, Mass.

The Wolf Benzine-Burning Safety-Lamp, by E. J. Schmitz, Columbia, S. C.

The Work of the Blast-Furnaces of the North Chicago Rolling-Mill Company, by Frederick W. Gordon, Philadelphia, Pa.

The Improved Brückner Cylinders, by R. W. Raymond, New York City.

The Specific Gravity of Low-Carbon Steels, by G. S. Miller, Mingo Junction, O.

The two following papers, originally read by title at the Chattanooga meeting, but subsequently withdrawn, were again read by title:

The Distribution and Proportions of American Blast-Furnaces, by John Birkinbine, Philadelphia, Pa.

Basic Refractory Materials, by Professor T. Egleston, New York City.

The following persons, duly recommended by the Council, were elected members and associates:

MEMBERS.

| | |
|---|---|
| Carl Angstrom, | Domnarvet, Sweden. |
| George H. Babcock, | New York City, N. Y. |
| Edgar G. Barratt, | Chicago, Ill. |
| William Brückner, | Marysville, Mont. |
| Walter H. Bunce, | Pueblo, Col. |
| E. Renshaw Bush, | New York City. |
| Frederick W. Christie, | Bedford Station, N. S. |
| Charles E. Clapp, | Pittsburgh, Pa. |
| Victor Deshayes, | Tamaris, Gard, France. |
| William P. Dewey, | San Francisco, Cal. |
| Mills R. Disosway, | West New Brighton, S. I., N. Y. |
| Walter F. Ferrier, | Montreal, P. Q. |
| Charles R. Fletcher, | Boston, Mass. |
| William Frear, | State College, Pa. |
| William C. Frick, | Danville, Pa. |
| Edwin Gilpin, Jr., | Halifax, N. S. |
| A. A. Hayward, | Renfrew Gold Mines, N. S. |
| Adolf Heberlein, | Butte City, Mont. |
| Thomas Hodgson, | Buffalo, N. Y. |

| | |
|---|---|
| Henry L. Hollis, | Braddock, Pa. |
| George Lawson, | Halifax, N. S. |
| W. O. Lentz, | Mauch Chunk, Pa. |
| Dennis McCarty, | Tombstone, Arizona. |
| Samuel McDonald, | Benwood, W. Va. |
| Edward W. Martin, | New York City, N. Y. |
| William G. Matheson, | New Glasgow, N. S. |
| Leverett S. Miller, | Troy, New York. |
| Stephen E. Noble, | Anniston, Ala. |
| Henry S. Poole, | Acadia Coal Company, N. S. |
| Robert M. Raymond, | Haile Gold Mine, S. C. |
| Jacob S. Robeson, | Braddock, Pa. |
| David S. Robinson, | Saltsburg, Pa. |
| Frank A. Ross, | Hecla, Mont. |
| Alfred W. Sims, | Orbisonia, Pa. |
| Charles G. Slack, | Aspen, Col. |
| George A. Smith, | South Chicago, Ill. |
| Ernest Sticht, | South Pueblo, Col. |
| Robert Sticht, | South Pueblo, Col. |
| Arthur L. Walker, | Globe, Arizona. |
| Stephen Wilcox, | New York City, N. Y. |
| Walter Wood, | Philadelphia, Pa. |

ASSOCIATES.

| | |
|---|---|
| Louis Brown, | New York City, N. Y. |
| Daniel C. Herr, | Harrisburg, Pa. |
| Simon H. Holmes, | Halifax, N. S. |
| S. A. Knapp, Jr., | Hawthorne, Nev. |
| George F. Peabody, | New York City, N. Y. |
| Charles S. Robinson, | Wareham, Mass. |
| Pemberton Smith, | Troy, N. Y. |
| Gray Staunton, | Hartford, Conn. |
| Edward I. E. Stetson, | Reading, Pa. |

The status of the following associates was changed to membership:

Arthur S. Dwight. | Eli Whitney, Jr.

The closing session was held Thursday evening, September 17th, in the hall of the Young Men's Christian Association, when the following papers were read:

The Geology of Natural Gas, by C. A. Ashburner, Philadelphia, Pa.

A New Method for the Determination of Phosphorus in Iron and Steel, by J. B. Mackintosh, New York City.

The Presidential Address was then delivered, the subject being The Engineer and the Wage-Earner. (This address is printed separately: see page 327.)

On motion of Mr. Wm. Kent, of New York City, heartily se
onded by several members, the thanks of the Institute were presente
to Mr. Bayles for his admirable and timely address.

On motion of Mr. J. D. Weeks, of Pittsburgh, Pa., the Secretar
was instructed to express to the governments of the Dominion an
the Province, the local committees, corporations, and citizens ge
erally, the thanks of the Institute for the great courtesy and hosp
tality shown to visiting members, and for the thoughtful an
thorough arrangements made for their comfort, pleasure, and profi
The President then declared the meeting adjourned.

## Excursions and Entertainments.

It is scarcely possible to enumerate—still less could this bri
report justly describe—the many courtesies extended to the Inst
tute in connection with this meeting. Both the government of th
Dominion of Canada, and that of the Province of Nova Scotia, mad
liberal appropriations for the purposes of a hospitable reception
free transportation was furnished over all parts of the Intercolonia
railway system; and so many excursions of importance and intere
were organized that it was impossible for any one of the guests
accept invitations to them all.

Wednesday afternoon was devoted to an excursion around th
beautiful harbor of Halifax, in the steamer St. Pierre.

Wednesday evening, the celebrated Public Gardens were illum
nated, and an open-air promenade concert, with fireworks, was give
in honor of the Institute.

Thursday morning, a large party of members and guests wa
driven in carriages from Dartmouth, opposite Halifax, to the Mon
tague gold-mine, a distance of about 8 miles. The mine and 2
stamp mill, belonging to the New Albion Gold Mining Compan
Limited (Chas. Annand, Managing Director), were examined, an
luncheon was served, the table being adorned with magnificent pyr
mids of gold-bearing quartz of extraordinary richness.

Friday morning, three parties left Halifax for as many differe
excursions.

An excursion to Londonderry and Springhill, tendered by th
Steel Company of Canada, and the Cumberland Railway and Co
Company, was carried out under the direction of Messrs. R. C
Leckie and G. Jamme. The party visited the interesting min

on-works at Londonderry, and the extensive coal-mines at hill, and was hospitably entertained at both places.

her party, under the guidance of Major-General Laurie, visited or, the St. Croix plaster-quarries, Grand-Pré, and Annapolis meeting everywhere the most cordial welcome and entertain- t the hands of the citizens, and enjoying *en route* a military on in the camp at Aldershott.

third and most numerous party combined an excursion to ctou coal-field, under the auspices of the Coal Managers' Asso- of Pictou and the town of New Glasgow, with a still longer Cape Breton, given by the Executive Committee and the Managers' Association of Cape Breton.

arton was reached at noon on Friday, and the Acadia, Drum- and Albion collieries were visited; also the steel-works and orks of New Glasgow, where a social reception was given evening, at the house of Mr. and Mrs. F. D. Laurie.

rday morning, a special train conveyed the party to Port ave, on the Strait of Canso, where the steamer Marion received and carried them through St. Peter's Bay and Canal, and through the lovely Bras d'Or lakes to Baddeck. On Satur- ening an impromptu entertainment was given at the Tele- Hotel.

Monday the party proceeded to Sydney, where, on that day e next, the Coxheath copper-mines, the Low Point, Bridge- Glace Bay, and Cow Bay coal-mines, Yeadon's patent fuel nery, the old town of Louisburg, etc., were visited. On ay evening a reception and ball were given by the citizens of .

Wednesday, in spite of a severe storm, the Sydney mines isited, after which the party was driven to the Little Bras nd regained the steamer Marion, returning to Port Mulgrave most delightful experience.

## MEMBERS AND ASSOCIATES PRESENT.

following members and associates made their presence known Secretary by registering their names at headquarters. The ncomplete, by reason of the neglect of some who were present e this registry. A large number of ladies attended the meet- d enjoyed the excursions.

A. V. Abbott.
H. W. Armstrong.
Charles Ashburner.
J. H. Bartlett.
J. C. Bayles.
F. P. Bemis.
H. Binsse.
T. A. Blake.
R. P. Bloss.
Stuart M. Buck.
R. C. Canby.
G. H. Clapp.
C. E. Clapp.
F. W. Clark.
F. Collingwood.
W. E. C. Coxe.
Frederick H. Daniels.
Charles W. Davenport.
George M. Davidson.
W. S. De Camp.
E. V. D'Invilliers.
W. F. Downs.
H. R. Durkee.
Charles E. Emery.
S. F. Emmons.
C. B. Finley.
Emerson Foote.
F. Lynwood Garrison.
John H. Harden.
John E. Hardman.
L. Holbrook.
C. B. Houston.
T. Sterry Hunt.
George Jamme.
William Kent.
Robert G. Leckie.
A. E. Lehman.
William Lilly.
Jawood Luken.
J. B. Mackintosh.
J. S. McLennan.
Alfred Markham.
Alfred J. Moses.
I. P. Pardee.
Willard Ide Pierce.
Joseph C. Platt, Jr.
R. W. Raymond.
Robert H. Richards.
C. Snelling Robinson.
Theo. W. Robinson.
R. P. Rothwell.
S. P. Sharples.
Pemberton Smith.
A. W. Sheafer.
E. Gybbon Spilsbury.
Gray Staunton.
C. A. Stetefeldt.
H. G. Torrey.
Willard P. Ward.
Joseph D. Weeks.
W. H. Wiley.

# PAPERS

OF THE

# XLIIId (HALIFAX) MEETING.

*SEPTEMBER, 1885.*

# *THE ENGINEER AND THE WAGE-EARNER.*

BY J. C. BAYLES, NEW YORK CITY.

(Presidential Address.)

GENTLEMEN OF THE INSTITUTE:

The first article of our organic law declares it to be one of the objects of our organization to promote the welfare of those engaged in our mining and metallurgical industries. But even in the absence of specific authority for a departure from the safe precedents of former years, I should still deem it fitting and desirable that our thoughts be from time to time directed to the great economic and social questions of the hour, as well as to problems of strictly technical interest, inasmuch as those of us who are actively engaged in professional work are in a position to be profoundly affected by any changes occurring in our industrial system. The engineer is not merely a student of the arts and sciences; he is a man of affairs, a business man, identified with the activities of trade. Labor is the instrument with which he must work, and the great problem of the relations of the wage-earning classes to those who employ them, and to society in general, is one of especial concern to those whose professional work places them in command of industrial enterprises.

However blind one may be to the spread and influence of socialistic teachings, there is little excuse for persistence in cherishing the idea that the wage-earner has no cause for dissatisfaction with his situation and prospects, or that his proper duty in life is to imitate the excellent example of the pious shepherd of Salisbury Plain, who derived supreme contentment from the fact that a kind Providence had vouchsafed him salt to eat with his potatoes. Since the French Revolution, of 1793, there has been a steady, and of late a rapid, progress of the socialistic movement. More general education, a free press, and organization for resistance or aggression have been the agencies by which the working classes have gained clearer ideas of their power and opportunities. The dull despair of mediæval servitude has given place to an intelligent and profound discontent with a situation which every year seems to make more hopeless;

and I do not hesitate to venture the opinion that, unless strong and willing hands are extended to lift them up, they will again and again reach from the mire to pull down and destroy that to which they cannot attain unaided. Blind Samson may stand chained, but if he shall bend himself upon the pillars against which he leans in sullen silence, the whole superstructure of society will come crashing to the ground; and nothing will restrain his purpose, should the mood seize him, even though that which he destroys must inevitably fall upon and crush him.

We have not time for even a superficial study of the conditions which obtain in the Old World, where upon the broad and patient shoulders of labor are piled burdens representing the accumulations of centuries of misgovernment, oppression, and useless wars. No doubt it would seem at first glance that in this great New World labor has no cause for dissatisfaction; that equal citizenship and a free ballot place each man's destiny in his own hands, and that European socialistic teachings have no chance to take root and grow in American soil. I grant that the conditions here are different from those existing in most countries of the Old World, and that the difference is in favor of the working classes of America; but even a casual examination of the relations which have already taken shape between the social classes here will show that we have grave problems of our own to consider which demand our most careful study. Of these the least serious are those which attract the attention of the newspapers and invite the interference of the police. The inflammatory utterances of nihilist refugees and the vehement orators of the Sand Lots, the resolutions passed at meetings of the so-called communists, and the impotent conspiracies of restless spirits who delight in planning revolution and destruction, may be dismissed as mere breaches of the peace. The movement which has in it the power and potency of unmeasured good or evil makes no threats, hides no incendiary torch and plots no secret deeds of violence. It does not rendezvous in beer cellars or organize mobs to terrorize our city authorities. It has organization, however, and is felt in the councils of the working classes. Even in free America socialism has gained more than a foothold, and its influence is already seen and felt in legislation directed against monopolies. The Granger movement in the Western States, the advocacy of the postal telegraph, the opposition to national banks, the outcry against land grants and subsidies, trade unions, national labor leagues, anti-monopoly leagues, coöperative insurance associations—these are a

few of the phases of socialism in its American aspects. All such movements are tending in one direction, and are prompted by the instinct of self-protection.

It is undoubtedly true that in no country of the world has the man with labor to sell so free a market in which to sell it as in America. The country is yet comparatively new, and there is still so much land open to settlement that mouths have not yet begun to multiply more rapidly than food. There are so many examples in which, under favoring conditions, industry and thrift have secured to the wage-earner independence, and even wealth, that those of us who have never known from personal experience what it is to overcome the difficulties which beset the mechanic in his struggle for self-improvement and social advancement, are very free with good advice for those who ask it, as well as for those who do not. But there is good reason to suppose that we know very little of the actual situation of the average workingman, and that we have no adequate conception of the strength of the cords which bind him down in the place which our industrial system has made for him. If Daniel Webster was right when he uttered the prophetic warning, "The freest Government cannot long endure when the tendency of the law is to create a rapid accumulation of property in the hands of a few, and to render the masses of the people poor and dependent"—we may with propriety consider whether even the foundations of the Republic are not menaced by the tendencies of the times.

In considering the position of the wage-earner in any one of our great industries, we must remember that the progress of half a century has closed to him many of the doors which once stood open to industry and thrift. The high perfection of the machinery employed in all branches of production has of necessity destroyed the apprentice system, or at least so much of it as was advantageous to the apprentice. The young man upon whom devolves the necessity of self-support has very little chance to learn a trade. He can and does learn a part of it, but, beyond acquiring a general familiarity with one or two operations in an industrial process, he reaches man's estate with very little more knowledge of the trade he has undertaken to master than he had when he began. His chances of gaining the comprehensive knowledge which is needed to fit him for advancement to responsible positions of management and direction, are so small that they may be said to be as nothing. His early education is such as boys without home advantages are likely to gain in the free schools, and of this he will retain only the elements. He can

read, write and compute in the four simple rules of arithmetic; but his mind is untrained, and unless he has a strong natural bent for study there is little likelihood of his supplementing the deficiencies of his education by systematic and profitable reading. Were he disposed to do this he could not find the books which would serve his purpose. Even elementary works presume a knowledge greater than his, and if he should make the attempt, as thousands of ambitious young mechanics have done, to improve his mind by reading the text-books of his trade, he would abandon the task, as thousands have before him, because between him and the beginnings of technical literature there is a gulf which he finds impassable. He knows his daily work and it yields him a support. The future is before him—full of hope, perhaps, but offering no tangible goal for his ambition. Restless and dissatisfied, he seeks change and usually finds it in marrying. He selects a wife from his own class—ignorant like himself, without purpose in life other or different from his own. His earnings will support a wife, living as the people of his class live, and he cuts off the slight remaining chance of bettering his condition by anchoring himself in the sphere to which he was born. The children which come to him are dear to his heart, but every one added to the number is only another millstone about the neck of his ambition. His home may be as happy and comfortable as a virtuous and industrious wife can make it with the slender resources at her command, but it is cramped and crowded, and the ever-present cradle is an obstacle to self-improvement which only genius can overcome. His youthful ambition matures into the hope that he will be able to earn food and shelter for his dependents. He realizes, however, that he is but a part of the great industrial machine, and that forces as far beyond his individual control as are those which hold the planets in their orbits, determine whether he shall attain the measure of even this reasonable hope. He works when it serves the purpose of capital that he shall work; he stands idle when capital orders production to stop. His savings in times of prosperity are consumed in times of depression, and the debts then incurred become a mortgage upon his future. His children have no brighter outlook than he had. As they grow up, each in turn must help carry the burden. Of what use is it to him to know that in the far West there are unmeasured acres of fertile land, and that he may have a farm for the asking? How shall he get there? How can he bridge the interval between leaving the daily work which feeds his family and reaping the harvest which that land would

yield? How shall he build his house and his barn and provide the implements of husbandry? Who will teach him how to break the virgin soil and plant the fruitful seed? He cannot escape from the servitude of his trade, whatever its vicissitudes. He is a free citizen of a free country, but the iron collar of "Gurth, Born Thrall of Cedric the Saxon," was lighter and more easily borne than are the shackles with which the exigent demands of his daily life have bound him hand and foot. His is not an isolated case. He is a type, and in considering his situation we have considered the situation of millions like him.

The wage-earner may be ignorant of science and the arts, and the sum of his exact knowledge may be only that which he has gained in his closely-circumscribed daily toil; but he is not blind, and his thoughts do not take the shape of daily and hourly thanksgiving that his condition is not worse than it is. He sees on every side the lavish display of wealth in which he has no part. He sees a large and growing class enjoying inherited abundance. He sees miles of costly residences, each occupied by fewer people than are crowded into single rooms of the tenement in which he lives. He cannot fail to reason that there must be something wrong in a system which effects such unequal distribution of the wealth created by labor. In the union, which is his only defence against the oppression of individual or corporate greed, he meets the thousand others who, like himself, feel that their only hope is in destroying the existing relations of labor and capital and substituting for them a better and more equable system of joint participation in the profits of production. He may reason wrongly, but it does not help the matter to tell him so. He may act on wrong impulses, but if repressed and defeated he will try again. The discontent and unrest of the working classes is to society, as at present organized, what Vesuvius was to Pompeii. When the pent forces burst their bonds asunder, who shall predict the consequences? The impulse to pull down and destroy, and to create equality in suffering because no other equality is possible, does not now exist as a purpose; but scarcely a year passes without giving evidence that it may flash into instant action, and that in the discontent of the working classes we have the potentialities of inestimable catastrophe.

As is always true in such cases, there is another duty than that involved in the repression of lawlessness created by the incendiary teachings of demagogues. The hopelessness of the position of the average wage-earner consists in his ignorance. The progress of the

arts has been so rapid that few men starting in life without education are able to keep pace with them, or, indeed, to acquire such familiarity with principles that they can hope to attain to responsible positions of management. While the sphere of those born to serve has been thus steadily narrowing, the sphere of those so fortunately situated that they have been able to acquire liberal education is steadily broadening. The capitalist is rarely safe in intrusting his interests in mining or manufacturing to the merely practical man. Success in business enterprises of every kind now depends upon so many things of which the merely practical man knows little or nothing, that management is usually intrusted to the man who combines education and experience, and his staff of responsible assistants is made up of young men of education who take subordinate positions to gain experience. It is in our great industries much as it is in the army. As vacancies are created among company officers they are filled by graduates from West Point, of which the supply usually exceeds the number of vacancies to be filled. Promotions from the ranks are infrequent, and properly so, for in the ranks are found very few men in any respect fitted to discharge the duties devolving upon commissioned officers, and they would be out of place among the educated men who have been trained to command. The soldier may grow gray in honorable service, but the highest to which he can attain is the chevron of a non-commissioned officer, which entails added duties and responsibilities without bringing release from any of the restraints and limitations which the rules of the service impose upon enlisted men. This comparison fails only in one respect; the wage-earner's term of service is never at an end. His future, in all but exceptional instances, promises nothing better than continuance in the labor he has learned, as a competitor with machinery which may at any time displace him, and force him to seek some other and perhaps less congenial employment, or starve. An industrial system which considers only the volume and economy of production has cut him off from the chance of learning the trade at which he works, and the schools from which he and his children can derive no benefit are furnishing graduates whose superior fitness for organization and management close to him every avenue of advancement. To dispense with the little skill he has gained is the constant aim of his superiors, and he can never know when arms of iron that tire not, and fingers of steel that work with mechanical precision, shall come to take his place, or when the progress of science shall discover ways of rendering his knowledge of no further

use. Is it to be wondered at that such a man is discontented and restless, and that if it is left to him to solve the great problem of a satisfactory readjustment of the relations of the classes he will try impracticable and dangerous methods, knowing no others? He has a grievance in the misfortune of birth under conditions which have given him little or no chance for self-improvement, and he rebels against his fate.

These are plain and practical truths known to us all, but perhaps not realized in all their grim significance. The dignity of labor is a fiction. To intelligence and education belong the dignity—to labor remains the burden. I know not how many hundreds of thousands of such men as I have described are commanded by the membership of this great Institute. As representatives of the "aristocracy of education" do we not owe them an obligation other and greater than can be discharged weekly at the pay window? The industrial system in which we are captains and lieutenants holds them inexorably in the ranks, while to us all the avenues of promotion are open. If the great problem of the improvement of the condition of the working classes is ever to be solved, we whose minds are trained to logical and purposeful thought, and who control the machinery of capital, must at least help solve it. For the idle and vicious there is nothing but the bitter fruits of idleness and vice. Those who break the inflexible laws of nature must expect to incur her inexorable penalties, and it would be a false and hurtful philanthropy which should seek to avert them. But for industry and thrift there should be something better than our present industrial system gives. Arbitration should decide fairly and impartially the issues between workman and employer, and some part of the profits of production should seek investment in ways which will react favorably upon the interests of labor. Participation should be established on an equable basis as the reward of faithful service, and co-operation should be promoted wherever and whenever it can benefit the wage-earners. What may be our duty in these directions depends upon what may be our opportunity. Wise leadership and direction for the labor movement will come, if at all, from the men of education who are carrying on for capitalists or corporations the productive industries of the country. The doctrines promulgated in the several schools of political, economic and Christian socialism are well worthy our careful and thoughtful study. Properly understood they are full of suggestions for the man who has the love of his fellow-men in his heart. Misunderstood, as they

are likely to be by the average wage-earner, they are as flaming brands thrown among inflammable material.

I do not take a sentimental view of this subject. My intercourse with the working classes has been sufficiently intimate to show me how little they invite generous and unselfish philanthropy. I know they are not docile and tractable; that they are suspicious of every offer made them; that they are short-sighted, unreasonable, obstinate and often ungrateful. I can understand how an employer may grow as hard and unsympathetic as a prison-keeper, conceding nothing and ever ready to press his advantage to the bitter end. I know that many schemes for the improvement of the condition of the working classes, prompted by the most generous impulses and consecrated by profound sacrifices, have ended in disappointment and humiliation, because the wage-earners have refused the helping hand held out to them, and have regarded the purest Christian philanthropy as a juggle of capital to entrap them into a yet more absolute dependence upon its bounty. But it is not always so, and the exceptions are many and conspicuous. I believe that the encouragement is great enough to warrant the experiment again and again.

Let us first dismiss from our minds all idea that legislation can deal with this delicate question, and try to remove the impression in the minds of the workingmen that all evils can be righted by the simple expedient of "Be it enacted." Herbert Spencer, in his startling essay on *The Coming Slavery*, shows how legislation sets in motion causes which cannot be checked when they have accomplished the object sought, but which go on producing effects often disastrous beyond estimation. Naturally, the workingman looks to legislation of his own framing as a means to the end he is seeking, and it is part of the duty of the more intelligent to point out to him the great danger that any law he may frame will become an agent in the hands of the governing classes for his further oppression. We should also dismiss from our minds the notion that we can assume the paternal relation towards our workpeople. Most philanthropic schemes have failed because conceived in the desire to make philanthropy take the shape of giving something for nothing. This is mistaken kindness. Either it exerts a pauperizing influence, making willing dependents of those whose only hope is in maintaining independence; or it imposes obligations which become irksome and are sooner or later repudiated. The idle, the vicious and the improvident will stay where they are, and it is where they belong.

The problem is to supply the ladder by which those who will may climb high enough to enjoy, not the bounty of charity, but some substantial good which they have acquired by the practice of the virtues which have ever been promotive of human welfare and the good of society.

I have no plan to suggest. One may well be distrustful of everything in the shape of off-hand solutions of a problem so complex and profound as that to which I have called attention. Each of us for whom it has a direct and personal concern must study it from his own point of view. He has little reason to hope that, like Œdipus in the fable, he will guess this riddle of the Sphinx; but that he can do something to establish more cordial relations between labor and capital, and to create that community of interest which long ago ceased to exist between them, is more than probable. My own idea of the first step in this direction should be a more conspicuous recognition of individual worth and capacity. A plan which deals with men by classes tends to destroy the incentive to individual effort to excel. Obviously, it is the interest of capital to hold out all reasonable incentives to those who have the ambition to rise above the average of their fellows, by making such self-advancement profitable. The trade-union tends to the establishment of an equality on the level of a low average; it will lose its power only when men who grade above the average secure a recognition and a protection from capital which leaves them nothing to expect at the hands of those whom they have left behind, content with a lower plane of skill and efficiency. In no other way can the ambition of young men in the ranks of labor be quickened, than to open for them a way in which they can secure an alliance with those who represent the power of capital, as the reward of zealous and intelligent service. What should be the second step would depend very much upon conditions necessarily local and, perhaps, temporary. I do not doubt, however, that, wherever the desire exists to do something for the benefit of labor, the means will suggest themselves in conference with those in the ranks of the workingmen whose counsel may be sought with advantage. We may dismiss from our minds all the dreams of the advanced socialists, and venture no impracticable experiments. We need recognize no rights as belonging to the working classes other than those which enlightened self-interest prompts us to concede. But within this safe territory of the practicable and the expedient we can find many opportunities for broad and intelligent philanthropy, which will be fruitful of good results

in readjusting the relations of the great social classes upon a safer and more stable basis. No one need consider unworthy of his most serious study a problem which in its many phases has commanded the profoundest consideration of some of the greatest minds of the century; no one need hope for another solution of it than will be found in well-considered and wisely-directed personal effort within the narrow spheres of individual influence.

---

## *THE AMALGAMATION OF GOLD-ORES, AND THE LOSS OF GOLD IN CHLORIDIZING-ROASTING, WITH ESPECIAL REFERENCE TO ROASTING IN A STETEFELDT FURNACE.*

BY C. A. STETEFELDT, NEW YORK CITY.

In May and June, 1885, I was engaged in examining the gold-ores of Las Minas, in the State of Vera Cruz, Mexico, with a view of finding a cheap and efficient method for extracting the gold.

The following minerals could be plainly seen in the ore: magnetite, pyrites of iron, pyrites of copper, quartz, and garnet. Neither galena nor zinc-blende were visible, but the ore contained a trace of lead, and in some samples of ore from the Muertos mine, 1.19 per cent. of zinc was found. Antimony and arsenic were not present. Native gold could scarcely be seen in specimens of the ore, and it only appeared—mainly in extremely fine particles—after pulverizing and washing. Magnetite was in every instance the most prominent mineral, its quantity varying between 43 and 67 per cent. Determinations of copper and sulphur showed that from 3.5 to 7 per cent. pyrites of copper, and from 3 to 22 per cent. pyrites of iron were present.

The gold-value of the ore varied between 0.3 oz. and 0.8 oz. per ton. I do not speak of specimens, but of average samples of large quantities of ore put through the battery. In ore that had been crushed through a No. 40 screen, the gold appeared, in part, as free gold, the rest being thoroughly mixed with the magnetite and pyrites, both minerals containing about the same percentage of gold. If this free gold was brought in contact with pure quicksilver it did not amalgamate readily, even if the quicksilver was charged with sodium amalgam.

All the gold-ores contained some silver, partly alloyed with the native gold, partly mineralized. But the silver-value was so low that it had to be entirely neglected in the metallurgical treatment.

That the gold-ores of Las Minas, on account of their pyritic character, were not fit for raw amalgamation, could be seen *a priori*, and the practical tests made at the mill had fully established this fact. Such ores can only be prepared for subsequent beneficiation by a complete roasting. Hence I directed my first efforts to roast the ore dead. By that I do not mean only a desulphurization of the pyrites, and a decomposition of the sulphates formed in roasting, but also a higher oxidation of the magnetite to ferric oxide.

### EXPERIMENTS IN ROASTING.

The ore was crushed wet by stamps (this being the only means of pulverizing at my disposal) with No. 40 screen on the mortar, and allowed to settle in a tank. In the sluice-boxes, between the battery and the settling-tank, the coarser particles of the native gold were caught. This arrangement was made in order to avoid errors of sampling, produced by coarse gold, in subsequent metallurgical experiments.

The roasting was done in a small reverberatory furnace. A charge of 500 pounds was all the furnace could conveniently take, but generally not more than 200 pounds were roasted, this quantity being more than sufficient for my metallurgical experiments.

*Charge No.* 1.—San Anselmo ore, with 64 per cent. magnetite. The charge contained, after 4½ hours' roasting, 44.8 per cent. magnetite. The solution, from a sample leached with water, gave no copper-reaction, the copper sulphate being already decomposed. Some aluminium sulphate was found. After 14½ hours the magnetite was only reduced to 42.3 per cent. After 16½ hours one-half of the ore was discharged. It still contained 39.6 per cent. magnetite.

*Charge No.* 2.—To the ore remaining in the furnace, 2½ per cent. of salt was added, and the charge stirred for 1 hour. It was now drawn into a pile and left in the furnace, firing being discontinued. After 4 hours the ore contained 20.7 per cent. magnetite, and after 8 hours 19.2 per cent. The ore was discharged after 22 hours. The magnetite had increased to 24.5 per cent. A sample, tested for copper, showed that in one ton of ore 0.44 pound of copper was present as cupric chloride, and 1.32 pounds as cuprous chloride.

*Charge No.* 3.—Muertos ore, with 47 per cent. magnetite. The

charge contained, after 5 hours' roasting, 35.7 per cent. magnetite, and considerable copper sulphate. After 7 hours 30.5 per cent. magnetite was found, and the copper sulphate had been entirely decomposed. After 17 hours one-half of the ore was discharged. It now contained 20.0 per cent. magnetite, no copper sulphate, but some aluminium sulphate.

*Charge No.* 4.—To the ore left in the furnace, 3½ per cent. salt was added, and treated like Charge No. 2, with this difference, that the furnace was kept hot by continued firing. After 3 hours the ore contained 6.2 per cent. magnetite, and much copper chloride. After 5 hours the magnetite had increased to 10.7 per cent., remaining at the same figure after 8 hours. The fire in the furnace was now stopped, and the ore discharged after 15 hours. It contained 11.8 per cent. magnetite. The cupric chloride had entirely disappeared, and only 0.6 pound of copper was present as cuprous chloride in one ton of ore.

*Charge No.* 5.—San Anselmo ore, with 65.7 per cent. magnetite. Mixed at once with 5 per cent. salt.

After 4 hours' roasting, a sample contained 1.6 per cent. magnetite, and considerable cuprous chloride. After 7 hours the magnetite had increased to 2.6 per cent. Firing was now stopped, the charge drawn into a pile, and left for 13 hours in the furnace. After discharging, the magnetite had increased to 5.6 per cent. Very little cuprous chloride was present, hardly sufficient for determination. A soluble aluminium salt was still left in the ore.

*Charge No.* 6.—San Anselmo ore, with 67.2 per cent. magnetite. Mixed at once with 5 per cent. salt.

After 1½ hours the magnetite had decreased to 18.6 per cent.; after 4½ hours, to 1.4 per cent. After 5½ hours the ore was discharged. It now contained 2.5 per cent. magnetite. In one ton of ore there were present 0.2 pound of copper as cupric chloride, and 0.6 pound of copper as cuprous chloride.

## Summary of Results.

These experiments present many interesting features. They show: *First.*—That a mere oxidizing-roasting leaves a large percentage of the magnetite intact, and that a continuation of the process is of very little benefit after the pyrites have been roasted dead. Some aluminium sulphate, resulting from decomposition of the garnet, remains undecomposed, a salt that would not interfere with any treatment to which the ore may be subjected.

*Second.*—A direct chloridizing-roasting removes the magnetite almost completely and very rapidily.

*Third.*—If the chloridizing-roasting is continued beyond a certain time, magnetite is re-formed, cuprous chloride becoming oxidized by withdrawing oxygen from ferric oxide. This is very evident in Charge No. 5.

*Loss of Gold in Chloridizing-Roasting.*

It remains, however, to record the most remarkable results of these experiments. In determining the gold value of the ore, before and after chloridizing-roasting, I found an enormous loss of this metal by volatilization. These results were so entirely unexpected that I first concluded an error had been made in the assays. Such was not the case, and in repeating the experiments, by roasting in a muffle, the facts were established beyond any doubt. In the latter case well-mixed samples were carefully assayed, and then one assay-ton mixed with three per cent. salt, roasted for one hour, and assayed after roasting.

*Charges Roasted in the Reverberatory Furnace.*

| NO. OF CHARGE. (See Roasting Experiments.) | GOLD VALUE. Before Chloridizing-Roasting. | GOLD VALUE. After Chloridizing-Roasting. | GOLD LOSS. In Per Cent. |
|---|---|---|---|
| No. 2, . . | 0.916 oz. per ton. | 0.426 oz. per ton. | 53.5 |
| No. 4, . . | 0.262 oz. " | 0.150 oz. " | 42.8 |
| No. 5, . . | 0.538 oz. " | 0.075 oz. " | 86.1 |
| No. 6, . . | 0.650 oz. " | 0.075 oz. " | 88.5 |

*Charges Roasted in the Muffle.*

| | | | |
|---|---|---|---|
| No. 1, . . | 0.700 oz. per ton. | 0.050 oz. per ton. | 93 0 |
| No. 2, . . | 0.525 oz. " | 0.075 oz. " | 85.7 |
| No. 3, . . | 0.650 oz. " | 0.065 oz. " | 90.0 |

There is no doubt that the volatilization of the gold takes place with that of the copper chlorides. The loss increased with the quantity of these chlorides formed and then volatilized.

This is shown by the much smaller loss in the reverberatory furnace charges, No. 2 and No. 4, in which the salt was added after a complete oxidizing-roasting, thereby reducing the formation of the copper chlorides to a minimum. Temperature and time of roasting must also influence the result.

That copper chloride is by no means an essential element in producing this loss is shown in the following experiments, made by Mr. C. Butters, with a gold-ore entirely free from copper. The gangue

of the ore was a very hard whitish quartz, intimately mixed with about 7 per cent. calcite. It contained 5.55 oz. silver, and 0.65 oz. gold per ton. In ordinary specimens neither silver minerals nor gold were visible to the naked eye. After concentrating a quantity of the ore, pulverized so as to pass a No. 40 wire-screen, and examining the concentrates under a powerful microscope, a dark steel-gray silver mineral was revealed, covered with minute crystals of gold. In several samples examined, all the gold appeared to be attached to the silver mineral, and none was seen by itself.

Besides, there was some pyrites of iron. In subjecting the ore to an oxidizing-roasting it assumed a pinkish color, and lost about 3 per cent. in weight, corresponding with the amount of carbonic acid driven out from the calcite. A loss in silver from 2 to 9 per cent. took place, but none in gold.

Very different were the results in chloridizing-roasting. These experiments were also conducted in the muffle, at a cherry-red heat. In roasting several samples for 1 hour with 5 per cent. salt, from 70 to 80 per cent. of the silver, and from 68 to 85 per cent. of the gold were lost. The chloridized ore assumed a dead-white color. After leaching it with water, the solution gave only a faint chlorine-reaction, the salt having been completely volatilized, and with it the larger portion of the precious metals. Roasting with 10 per cent. salt did not increase the loss in silver and gold.

The ores in both experiments were of an uncommon and peculiar character and contained the gold in exceedingly fine particles.

While I am not prepared to say, upon experimental proof, in what form the gold is volatilized in chloridizing-roasting, I would suggest that it escapes as a double salt. If this is the case, the loss will depend—other circumstances being the same—upon the volatility of the chloride with which the gold chloride is combined. Now, the chlorides of copper are much more easily volatilized than sodium chloride, and the loss should be greatest in case copper is present in the ore, as is actually shown by my experiments.

Plattner speaks of the loss of gold in oxidizing-roasting, but entirely neglects chloridizing-roasting. G. Kuestel records a loss of 8 per cent. of gold in roasting telluret-ores with salt, and states that by increasing the temperature and time of roasting, the loss in gold may be 20 per cent. and more. Mr. R. P. Rothwell has drawn my attention to C. H. Aaron's book on leaching gold- and silver-ores. Aaron suffered heavy losses in the chloridizing-roasting of gold-bearing sulphurets, and in making tests in a muffle, lost more

than 50 per cent. of the gold. Both Kuestel and Aaron neglect to give details of their experiments. In Australia, the chloridizing-roasting of gold-ores was abandoned on account of heavy losses.

I have repeatedly expressed the opinion that the volatilization of metals in roasting is principally a function of time. My experiments in the chloridizing-roasting of silver-ores have established this fact in the case of silver. Why should it not hold good with regard to gold? The advantages of instantaneous roasting, as done in the Stetefeldt furnace, are as yet very little understood and appreciated by metallurgists. It is erroneously assumed that this system, for which the Germans have coined the word *Staubstromröstung*, is only of very limited application. Leaving all economical and mechanical questions out of consideration, the system of instantaneous roasting has three great advantages, namely:

1st. The loss of precious metals is reduced to a minimum.

2d. The roasted ore is in the most favorable condition for subsequent treatment.

3d. The fine ore-particles accumulating in the dust-chambers are thoroughly roasted.

The last-named point, being one of the essential features of the Stetefeldt furnace, is too well known to require any discussion. To ascertain the loss of precious metals by experiments on a large scale in a direct way, namely, by weighing and sampling the ingoing raw ore and the outgoing roasted ore, is attended with so much inconvenience and expense, that I have not found parties in charge of any mill employing Stetefeldt furnaces willing to undertake it. Hence I had to get at the question by an indirect method. If a sulphuret ore is subjected to an oxidizing-roasting, the outgoing elements are generally of greater weight than the ingoing ones, and the result is a loss in weight. The same is the case in chloridizing-roasting, provided we compare the weight of the raw ore, without salt, with the weight of the roasted ore after leaching out the soluble salts. Under the circumstances it follows that the assay-value of the roasted ore must be greater than that of the raw ore, in proportion to the loss in weight the latter has suffered, provided no silver has been volatilized. If, however, the roasted ore should fail to come up to the required value, no other inference can be drawn but this: that silver has been lost in roasting.

In 1880, I carried out at the Ontario mill, Utah, under circumstances that are not likely to occur again, a series of comparative experiments in the Stetefeldt and Howell furnaces. In one of these

experiments the ore treated by both furnaces was exactly the same. It came from the same stamp-battery, and, after being elevated to a hopper, was distributed from the spout of a conveyer-trough, one-half going to the Stetefeldt and the other half to the Howell furnace. The latter had been provided with a system of dust-chambers as complete and well-constructed as that attached to the Stetefeldt furnace. The roasted ore was discharged into cars and carefully sampled. At the end of the experiment, the dust-chambers were cleaned out. The average result, after a run of six days, was as follows:

| | |
|---|---|
| Value of raw ore, . . . . . | 106.0 oz. silver per ton. |
| Value of roasted ore, after leaching with water: | |
| From Stetefeldt furnace, . . . . . | 112.5 oz. silver per ton. |
| From Howell furnace, . . . . . | 98.1 oz. " " |

Difference: 14.4 oz. silver per ton, or 13.5 per cent. of the silver in the ore. This difference represents the loss of silver by volatilization in the Howell furnace above that in the Stetefeldt furnace. That the latter must be very small is evident from the much higher value of the roasted ore compared with the raw ore. The increase in value corresponded very nearly with the loss in weight, as ascertained by muffle-tests, which the raw ore suffered in roasting. In these experiments, from 25 to 28 tons of ore were roasted per day, and divided between the two furnaces, running them only at half capacity. In regard to the Howell furnace, this had the effect of keeping the ore much longer in the cylinder than if the latter had received its full charge of 25 tons. Subsequently the Howell furnace was kept running for 10 days at full capacity, receiving the ore from 20 stamps, and the Stetefeldt furnace was supplied from another battery of 20 stamps. The results from the Howell furnace were as follows:

| | |
|---|---|
| Value of raw ore, . . . . . | 120.6 oz. silver per ton. |
| Value of roasted ore, . . . . . | 115.5 oz. " " |
| Difference, . . . . . | 5.1 oz. " " |

or the roasted ore was 4 2 per cent. lower in value than the raw ore.

The results from a 40 days' run of the Stetefeldt furnace were as follows:

| | |
|---|---|
| Value of raw ore, . . . . . | 109.8 oz. silver per ton. |
| Value of roasted ore, . . . . . | 115.8 oz. " " |
| Difference, . . . . . | 6.0 oz. " " |

or the roasted ore was 5.4 per cent. higher in value than the raw ore. This makes a difference of 9.6 per cent. between the two furnaces, and represents the loss of silver in the Howell furnace above that taking place in the Stetefeldt furnace. In comparing the losses of silver resulting in the two experiments, we have again a confirmation of my theory of the influence of time. When the Howell furnace was running at half its capacity, and the ore remained longer in the cylinder, the loss in silver was 3.9 per cent. greater than in the second experiment, when the furnace was run at full capacity. The character of the Ontario ore is such that these losses are by no means astonishing. It contains nearly all its silver as a fahl-ore, rich in antimony and arsenic, and carries a large percentage of zinc-blende. In conducting the process in the Howell furnace, it was necessary to roast at a slightly higher temperature than in the Stetefeldt furnace. With a low fire, the ore had a tendency to run forward in the cylinder, and get discharged while still partly raw. The average value of the tailings resulting from the amalgamation of the roasted ore was so nearly uniform that any difference was within the limit of errors in sampling. This shows that the roasting was equally well done in every instance.

At the Lexington Mill, Butte, Montana, a silver-ore that contains a considerable amount of gold is subjected to a chloridizing-roasting in the Stetefeldt furnace. The ore is composed of silver-bearing pyrites of iron, pyrites of copper, zinc-blende, galena, and some native silver, with a quartz gangue, sometimes replaced by silicate of manganese. Antimonial and arsenical silver-minerals are absent. Native gold is not visible. From the character of this ore, we can safely infer that it will lose less silver in roasting than Ontario ore, and that in a Stetefeldt furnace this loss must be exceedingly slight. Now if, in the roasted ore, the proportion of silver and gold remains the same as in the raw ore, it follows that also the loss in gold must be very small. I give below such statistics as are in my possession, but will take up this subject again when I can supply more facts.

The average of about 600 samples, taken at the Lexington mill, from October, 1883, to August, 1884, and compiled from the monthly averages of the assayer's report is as follows:

| | |
|---|---|
| Raw ore, . . . . . | 45.9 oz. silver; 0.77 oz. gold per ton. |
| Roasted ore, after leaching out soluble salts, | 50.0 oz. silver; 0.84 oz. gold per ton. |
| Increase in value, . . . . | 4.1 oz. silver; 0.07 oz. gold per ton. |
| Increase in value, . . . | 8.8 per cent. silver; 9.1 per cent. gold. |

From this it would appear that the loss of gold in chloridizing-roasting in the Stetefeldt furnace is somewhat less than that of silver. The difference, however, in the increase of value between silver and gold is only 0.3 per cent., and within the limits of errors in assaying.

Finally, I wish to say a few words about the advantage of instantaneous roasting in relation to a peculiar condition of the roasted product. The most striking facts I have already presented in my paper on Russell's Process.* I refer to paragraph 19, which contains the experiments in lixiviating ores subjected to an oxidizing-roasting. If ores were roasted in the muffle, the amount of silver that could be extracted by hyposulphite solutions decreased rapidly with an increase of time in roasting. If, however, the ore had been roasted in a Stetefeldt furnace, as much as 85.7 per cent. of the silver could be extracted by Russell's process. It is not to be assumed that different combinations of silver are formed by the instantaneous process of roasting, but that the silver compounds formed are more easily soluble on account of their short exposure to heat. We know, for instance, that peroxide of iron becomes quite insoluble in dilute acids after being exposed to a high temperature for a long time. The same is the case, but less pronounced, with other oxides. Instances of this kind might be multiplied.

## EXPERIMENTS IN AMALGAMATION.

Taking into consideration the low grade of the Las Minas gold-ores, the high price of salt and chemicals in Mexico, and the local resources and facilities of the country generally, I became convinced that extraction of the gold by amalgamation, after previous oxidizing-roasting, would be the only economical process. With this object in view, the following experiments were undertaken. In experimenting with such gold-ores there were only two ways possible: either to work very large quantities, or to make tests on such a small scale that the results possessed analytical exactness. The latter course was the only one that could be pursued. These experiments being somewhat novel and surprising in their results, it will be necessary to enter into details. The apparatus used consisted of one iron mortar, five inches in diameter, with a rather flat bottom (F. M.); one iron mortar, five inches in diameter, with a concave bottom (C. M.); and one wedgewood mortar, with concave bottom (W. M.). In grinding the charges, the iron mortar with flat bottom proved to

* *Transactions*, vol. xiii., p. 47.

give superior results as compared with the iron mortar with concave bottom—its grinding effect was the best. The iron mortars were used to imitate the work of an iron pan; the wedgewood mortar that of an arrastra. The charges consisted of five assay-tons of roasted ore (1 A. T.=29.166 gm.). This was ground or mixed with water and quicksilver, the latter being added either immediately or after the ore had been treated with other reagents (10 gm. quicksilver to a charge of 5 A. T. of ore).

The charges were amalgamated either at ordinary temperature or with heating. The latter method had no beneficial effect.

After the amalgamation had been completed, the charge was thinned with water, and gently stirred, until the quicksilver was united. For separating the tailings from the quicksilver, an enameled iron pan (8 inches diameter on the top, 6¼ inches diameter at the bottom, 1½ inch height) was used. With a little skill and practice, with the aid of potassium cyanide, if necessary, the quicksilver was easily gathered in one mass, and transferred to a beaker-glass. It was now dissolved in nitric acid. Here the following phenomena were observed: In case only a trace of copper, and very little silver had been amalgamated, the gold remained at the end of the operation as a spongy globule that could be easily transferred to a drying-cup. The gold so obtained was, however, not perfectly pure. It had to be packed into a piece of lead-foil, inquartated with silver, cupelled, and the alloy redissolved in the customary way. If considerable copper had been taken up in amalgamation, the gold appeared as an exceedingly fine powder—after solution of the quicksilver. It became necessary to filter the solution, collect the gold on the filter, incinerate the latter, and cupel the ashes as above. The presence of a large amount of silver produced a similar but less pronounced effect, and also in this case filtering was necessary. It will be seen that these tests must give a positive and very accurate result. That in every instance the gold-value of the charges was ascertained in the most careful manner, and all reagents tested for their purity, it is hardly necessary to mention. In all, fifty-one charges were amalgamated, and those giving the most interesting results are recorded below:

No. 1.—Roasted San Anselmo ore, from charge No. 1 of "roasting experiments." It contained 39.6 per cent. magnetite. No copper sulphate present. The charge had been roasted for 16½ hours. Time of amalgamation 3 hours, with quicksilver added at once. Time of settling ½ hour. (Time of settling the same in all subsequent experiments.)

Value of ore, 0.916 oz. gold per ton.

Extracted, 0.195 oz. gold per ton, or 21.2 per cent.

No. 2.—San Anselmo ore, from charge No. 5, roasted chloridizing. It contained 5.6 per cent. magnetite, and a very slight amount of cuprous chloride.

Quicksilver added at once. Time of amalgamation, 2½ hours.

Value of ore, 0.075 oz. gold per ton.

Extracted, 0.060 oz. gold per ton, or 80.0 per cent.

No. 3.—San Anselmo ore, from charge No. 1, sifted through a No. 80 screen.

It contained 26.6 per cent. magnetite. No copper sulphate.

Grinding, 1 hour; then quicksilver added. Time of amalgamation, 2½ hours.

Value of ore, 0.450 oz. gold per ton.

Extracted, 0.125 oz. gold per ton, or 27.7 per cent.

No. 4.—The same ore as in No. 3.

Grinding, 1 hour; then 1.5 gm. mercuric chloride added, and a few drops hydrochloric acid (Designolle process), and worked for ¾ of an hour; then quicksilver added, and amalgamated ¾ of an hour longer.

Value of ore, 0.450 oz. gold per ton.

Extracted, 0.345 oz. gold per ton, or 76.6 per cent.

In repeating these charges (Nos. 3 and 4), but without previous grinding, adding quicksilver in one case, and mercuric chloride in the other at once, and amalgamating for 2½ hours, ordinary amalgamation extracted 31.1 per cent., and the Designolle process 82.2 per cent. of the gold.

Further experiments with the Designolle process, in which the mercuric chloride was reduced to 0.5 gm. per charge of 5 A. T., gave less favorable results, extracting only from 51 to 56 per cent. of the gold.

All the above charges were worked in iron mortars.

No. 5.—Blanket-washings, from San Anselmo ore, roasted oxidizing for 4 hours, contained 19.5 per cent. magnetite. Copper sulphate completely decomposed. (These blanket-washings were obtained in crushing 70 tons of San Anselmo ore for the purpose of sampling it.)

In order to imitate the working of a pan by first grinding without quicksilver, and then amalgamating with raised muller, the ore was ground in the iron mortars for 1½ hours; then quicksilver added, and for 1 hour amalgamated by stirring with wooden pestles.

Value of ore, 1.48 oz. gold per ton.

Extracted in F. M., 0.82 per ton, or 55.4 per cent.

Extracted in C. M., 0.75 per ton, or 50.6 per cent.

In the following charges the same ore was ground for ¾ of an hour, and then quicksilver added and amalgamated with iron pestles, under grinding, for 1½ hours, with these results:

Extracted in F. M., 1.40 oz. gold per ton, or 94.6 per cent.

Extracted in C. M., 1.09 oz. gold per ton, or 73.3 per cent.

Finally, the quicksilver was added at once, and the charges amalgamated for 2½ hours with grinding.

Extracted in F. M., 1.42 gold per ton, or 95.9 per cent.

Extracted in C. M., 1.23 oz. in gold per ton, or 83.1 per cent.

No. 6.—San Anselmo ore, roasted oxidizing for 4 hours. The raw ore contained 67 per cent. magnetite, and the roasted ore 31 per cent. Immediately after discharging no copper sulphate was present, but after cooling it appeared to some extent, undoubtedly in consequence of the presence of aluminium sulphate.

Quicksilver being added to the charge, the amalgamation was continued for 2½ hours.

Value of ore, 0.800 oz. gold per ton.

Extracted in F. M., 0.355 oz. gold, or 44.3 per cent.

Extracted in C. M., 0.340 oz. gold, or 42.5 per cent.

No. 7.—The same ore as in No. 6 was treated in this experiment. But, in place of quicksilver, pure silver amalgam was added (a piece the size of a pea) and the charge ground for 2 hours. Then quicksilver was added, and amalgamated ½ of an hour longer, to collect the amalgam, before settling was commenced.

Value of ore, 0.800 oz. gold per ton.

Extracted in F. M., 0.620 oz. gold, or 77.5 per cent.

Extracted in C. M., 0.565 oz. gold, or 70.6 per cent.

The silver amalgam in the last experiment was moist. In using silver amalgam that was much drier, but by no means hard, the following results were obtained:

Extracted in F. M., 0.676 oz. gold per ton, or 84.0 per cent.

Extracted in C. M., 0.660 oz. gold per ton, or 82.5 per cent.

No. 8.—Muertos ore, roasted oxidizing. Contained 43 per cent. magnetite before, and 19.5 per cent. after roasting. This ore was discharged, by mistake, too soon. A considerable part of copper sulphate had remained undecomposed. Two charges were amalgamated, one in the iron mortar with flat bottom, and the other in the wedgewood mortar, both with silver amalgam. Time of amalga-

mation, 2½ hours; then quicksilver added and amalgamated ½ of an hour longer.

Value of ore, 0.370 oz. gold per ton.

Extracted in F. M., 0.120 oz. gold, or 31.6 per cent.

Extracted in W. M., 0.316 oz. gold, or 83.1 per cent.

The amalgam from the iron mortar was very base, that from the wedgewood mortar very fine.

No. 9.—Muertos ore, roasted oxidizing. Contained 28 per cent. magnetite after roasting. A well-roasted charge, showing not a trace of copper sulphate after discharging. After cooling, a slight quantity of copper sulphate was, however, re-formed.

The amalgamation was carried out with silver amalgam as in previous experiments, but the amalgam squeezed very dry.

Value of ore, 0.340 oz. gold per ton.

*a.* Extracted in F. M., 0.296 oz. gold per ton, or 87.0 per cent.

Extracted in C. M., 0.286 oz. gold per ton, or 84.1 per cent.

*b.* Extracted in F. M., 0.270 oz. gold per ton, or 79.4 per cent.

Extracted in W. M., 0.332 oz. gold per ton, or 97.6 per cent.

*c.* Extracted in F. M., 0.292 oz. gold per ton, or 85.9 per cent.

Extracted in W. M., 0.326 oz. gold per ton, or 95.9 per cent.

If the magnetite was ground sufficiently fine, it did not interfere with good settler work. In all these experiments no flowering of quicksilver took place, in spite of the grinding; it united without difficulty, and a loss was hardly preceptible.

The amalgam from the charges worked in the iron mortars contained some copper, even if the ore was apparently free from copper sulphate, while the amalgam from the wedgewood mortar was always fine, no matter how much copper sulphate had been left undecomposed in the ore.

## Summary of Results.

These results are of great interest and importance, and throw considerable light upon gold-amalgamation generally. It has often been found extremely difficult to extract a high percentage of gold from roasted ores by pan-amalgamation, and the theory of "rusty gold" has been extensively circulated in metallurgical literature to explain this fact. It has also been found more difficult to extract the gold from gold-bearing silver-ores by pan-amalgamation, especially if the roasting has been conducted in a reverberatory furnace and not by the instantaneous process. From my experiments it appears that in all these cases the low results are due neither to

imperfect roasting nor to the formation of gold combinations which cannot be amalgamated, but to the defects of pan-amalgamation itself. My experiments lead to the following conclusions:

*First.*—That the ore should be well roasted in as short a time as possible. A complete change of the magnetite to ferric oxide is not necessary, and even a large percentage of this mineral may remain unaltered without producing an injurious effect.

*Second.*—That copper, if it enters the amalgam, even in small quantities, prevents in a great measure the amalgamation of the gold. Lead will no doubt act still more injuriously. Hence, the amalgamation in an arrastra, where no iron is exposed, will give far better results than if the process is conducted in an iron pan. Considerable copper sulphate may be present in the ore without materially impairing the result in an arrastra.

*Third.*—The amalgamation of finely divided gold requires friction, and contact alone with quicksilver is not sufficient. But more than that: liquid quicksilver eludes in a great measure the contact with gold, and it is necessary to amalgamate with gold-amalgam (for which silver-amalgam was substituted in my experiments, and should be in starting works on a large scale). This amalgam should not be too soft, so that in the process of grinding liquid quicksilver is not pressed out. I have repeatedly drawn attention to the fact that in amalgamation generally great fineness of the material treated is injurious, and need only to point out the difficulty experienced in working raw slimes, or the fine dust from roasted silver-ores.

*Fourth.*—Other conditions being equal, the result of amalgamation depends upon the grinding efficiency of the apparatus used. The much better yield in the iron mortar with flat bottom, as compared with the iron mortar with concave bottom, demonstrates this clearly. In grinding effect, the wedgewood mortar was about equal to the iron mortar with concave bottom; but in spite of this, it always yielded higher results than the best grinding iron mortar. Hence the arrastra is, under all circumstances, the best amalgamator. It is hardly necessary to state that the arrastra must be so constructed that iron does not come in contact with the ore.

*Fifth.*—Experiment No. 5 gives exceptional results. They are, however, explained, if we take into consideration the character of the ore treated. This charge, being a product of concentration, contained most of the gold in comparatively coarse particles, which are readily taken up by quicksilver. In this case, too, grinding was essential, and mere mixing gave low results.

*Sixth.*—These facts throw some light upon the working of the Designolle process. The small quantity of quicksilver reduced from the mercuric chloride, by contact with iron under friction, produces at once solid gold amalgam, and the latter is really the effective reagent.

The amalgamation of gold-bearing silver-ores which have been subjected to a chloridizing roasting cannot be conducted in an arrastra. In such cases it may be profitable to extract by the arrastra process the gold remaining in the tailings.

That an arrastra, the bottom of which is covered with gold amalgam, is the most effective apparatus for amalgamating gold, has been known to the Mexicans for more than 200 years. I may claim to have rediscovered this fact by scientific research. To my knowledge, no series of experiments has ever been carried out before like that recorded in this paper.

If the Las Minas ores are roasted in a Stetefeldt furnace, and amalgamated in arrastras, there is not the slightest doubt in my mind that from ninety to ninety-five per cent. of the gold can be extracted. Besides, the process is well-suited to the country, and the Mexicans understand its manipulations thoroughly.

## METALLURGICAL TREATMENT ON A LARGE SCALE.

This would comprise the following operations:

*First.*—Crushing the ore in a rock-breaker.

*Second.*—Drying the crushed ore.

*Third.*—Pulverizing by Krom's improved rolls, and screening through No. 30 wire-cloth.

*Fourth.*—Roasting in a Stetefeldt furnace.

*Fifth.*—Amalgamating in arrastras.

*Sixth.*—Settling in American settlers, such as are used in silver-mills.

*Seventh.*—Straining the quicksilver, retorting the amalgam, and melting the bullion into bars.

At Las Minas there is ample water-power, and ordinary labor and fuel are very cheap. I have shown, by careful estimates, that under the existing favorable conditions, and with an output of 120 tons per day, the expense of mining and reduction would be as follows, viz.:

| | |
|---|---|
| Mining, | $1.27 per ton. |
| Transportation, | 0 42 " |
| General expenses and skilled labor, | 1.19 " |
| Ordinary labor, | 0.41 " |
| Wood, | 0.21 " |
| Wear and tear of machinery, lubricants, quicksilver, etc., | 0.90 " |
| Interest and amortization on a capital of $250,000, | 0.78 " |
| Total expense, in gold, | $5.18 |

Hence ores of a very low grade can be worked with a profit.

---

## *THE PRESENT VALUE OF STEEL CASTINGS.*

BY ARTHUR V. ABBOTT, NEW YORK CITY.

DURING the past four years I have had occasion to make quite extensive use of steel castings in the manufacture of testing-machines and large scales for Messrs. Fairbanks & Co. The failure of some of these castings at stresses much below those which were claimed for them by the makers, induced me to institute a series of experiments to determine the actual constructive value of the steel castings now to be obtained in this country. The art of steel-casting is rapidly improving, almost every issue of the scientific press bringing accounts of some new development; consequently, the results of the following experiments are only exponents of the value of steel castings as at present made.

In order to make the examination as thorough as possible, ten sets of patterns were made and forwarded to as many different firms in the country who advertised to make steel castings. The first part of the accompanying table gives a list of these manufactures, together with the price per pound. The order accompanying the patterns simply requested the manufacturer to supply two castings from each pattern of his ordinary product of steel. These castings were sent to me and paid for in the usual manner, so that it is probable that the samples fairly represent the quality of the average of steel castings, and are free from the suspicion of being "special runs." Two patterns were sent to each maker, one being a straight

bar 2 inches square and 30 inches long, and intended to supply samples for tests in compression and transverse stress, the other being a bar 1½ inches square for a distance of 6 inches on each end, and turned round for a space of 12 inches in the center, and designed to furnish tension test-pieces. Two castings from each pattern were ordered, so that any questionable result could be checked by duplicate experiments. The intention in commencing this investigation was to make tests in tension, compression, and transverse stress on samples from all the makers, and then, as a matter of additional information, to supplement the physical tests with a chemical analysis. Unfortunately from only seven of the ten manufacturers samples were received; and so much delay has been experienced in obtaining these, that at present I am only able to give the results of the physical tests, and shall be obliged to postpone the account of the chemical investigation to a future paper.

*Name of Company.*

| No. | | Price per lb. |
|---|---|---|
| 1. | Solid Steel Casting Company, Alliance, Ohio, | 10 cents. |
| 2. | I. G. Johnston & Co., Spuyten Duyvil, N. Y., | 12 cents. |
| 3. | S. G. Fagg & Co., Philadelphia, Pa., | 12 cents. |
| 4. | Chester Steel Casting Company, Chester, Pa., | 11 cents. |
| 5. | Solid Steel Casting Company, Mills Building, New York City, | — |
| 6. | Pittsburgh Steel Casting Company, Pittsburgh, Pa., | 10 cents. |
| 7. | McIntosh, Hemphill & Co., Pittsburgh, Pa., | 10 cents. |
| 8. | Cowing Steel Casting Company, Cleveland, Ohio, | — |
| 9. | Standard Steel Casting Company, Thurlow, Pa., | 10 cents. |
| 10. | Eureka Steel Casting Company, Chester, Pa., | 10 cents. |

*Tension.*

| No. | Elastic limit. Lbs. per sq. in. | Ultimate. Lbs. per sq. in. | Elongation. Per cent. | Reduction. Per cent. | Modulus. |
|---|---|---|---|---|---|
| 1 | 28,923 | 43,631 | 6 00 | 0 72 | 25,150,000 |
| 2 | 25,610 | 36,880 | 0.40 | 0.82 | 24,000,000 |
| 2 | 25,650 | 42,280 | 0.80 | 1.20 | 21,000,000 |
| 2A | 20,000 | 30,920 | 0.20 | —— | 20,920,000 |
| 3 | 23,116 | 44,221 | 6.00 | —— | 18,000,000 |
| 4 | 21,395 | 38,301 | 10 00 | —— | 23,773,000 |
| 6 | 31,180 | 46,156 | 2.00 | —— | 27,600,000 |
| 7 | 35,840 | 56,724 | 10.00 | 2.07 | 25,150,000 |
| 9 | 35,445 | 52,330 | 9.00 | 1.47 | 28,325,000 |
| 9A | 38,217 | 63,058 | 29.88 | 19.88 | ———— |
| 9A | 38,217 | 62,816 | 20.50 | 18.18 | ———— |
| 10 | 17,522 | 32,151 | 8.00 | 3.42 | 20,000,000 |

*Compression.*

| No. | Elastic limit. Lbs. per sq. in. | | | | Modulus. |
|---|---|---|---|---|---|
| 1 | 35,011 | —— | —— | —— | 23,333,000 |
| 2 | 31,250 | —— | —— | —— | 30,000,000 |
| 2A | 25,140 | —— | —— | —— | 15,712,000 |
| 3 | 24,350 | —— | —— | —— | 19,000,000 |
| 4 | 26,750 | —— | —— | —— | 20,600,000 |
| 6 | 29,703 | —— | —— | —— | 21,000,000 |
| 7 | 36,110 | —— | —— | —— | 24,000,000 |
| 9 | 27,027 | —— | —— | —— | 20,800,000 |
| 10 | 20,408 | —— | —— | —— | 19,000,000 |

*Transverse.*

| No. | Elastic limit. Lbs. per sq. in. | Ultimate. Lbs. per sq. in. | Deflection. In. | | Modulus. |
|---|---|---|---|---|---|
| 1 | 6,000 | 8,000 | 0.72 | —— | 20,000,000 |
| 2 | 2,500 | 3,870 | 0.45 | —— | 19,000,000 |
| 2 | 2 600 | 3,950 | 0.52 | —— | 19,000,000 |
| 2A | 2,500 | 3,535 | 0.31 | —— | 18,000,000 |
| 3 | 3,000 | 4,181 | 0.88 | —— | 20,830,000 |
| 4 | 3,750 | 5,720 | 0.15 | —— | 20,550,000 |
| 6 | 4,000 | 6,259 | 0.60 | —— | 20,000,000 |
| 7 | 4,000 | 5,480 | 0.20 | —— | 25,000,000 |
| 9 | 4,000 | 6,810 | 0.21 | —— | 28,000,000 |
| 10 | 2,500 | 4,010 | 0.35 | —— | 20,000,000 |

In my own practice I find it necessary to do very little machine-work on steel castings; consequently, the patterns for the test-pieces were designed to furnish castings that could be placed in the testing-machine just as they came from the sand, without any machine-work. By this means it was hoped to embrace in the results the element of an undisturbed skin, which is generally considered so important in castings. My impression is that, in the case of true steel castings, the skin tends to decrease the strength, as it seems to be less ductile than the interior, and, yielding first under stress, assists the failure of the whole. Consequently, I am of the opinion that the results of the experiments I have made would have been higher if the outer surface of the test-pieces had been removed. Additional investigation is required to demonstrate this; yet the accompanying results may be taken as a fair indication of the value of steel castings, when used without the removal of the outer layers.

In the tension and transverse pieces, the samples were placed in the machine just as they were received from the makers, but the compression specimens had each end trued off, so as to obtain a fair

bearing against the compression-plates. The rest of the casting was left undisturbed, so as to give a comparison with the results given by other stresses.

All the tests were made on the testing-machine used by me in the department of tests and experiments, Fairbanks & Co., New York City. The ultimate strength of any material is always a very uninteresting quantity. The elastic strength is, on the contrary, very valuable, for it is the only guide that can lead the engineer to successful construction. Usually the elastic strength is some definite ratio of the ultimate resistance, but in steel of different compositions, and especially in steel castings, where so much depends on the crystallographic arrangement of the particles, this ratio may vary very considerably. Consequently, in these experiments I have taken the greatest care to accurately determine the elastic limit and modulus of elasticity, and have given comparatively little attention to the ultimate strength; indeed, for want of time, the ultimates in compression have been omitted. In tension, compression, and transverse stress each piece was put in the testing-machine and submitted to regularly increasing loads of as nearly as possible 1000 pounds per square inch of section, and the deformation of the specimen measured to $\frac{1}{10000}$ inch. As long as the increments of deformation were proportional to the increments of stress, the loads were assumed to be inside the elastic limit, and the point at which they became disproportionate was taken as the limit; consequently, the elastics here given may be relied on to be correct within 500 pounds per square inch.

The results of the tension and compression tests have been reduced to pounds per square inch and the elongation and reductions to per cent., and, excepting in the cases of those tests marked "A," all the experiments have been made on bars of the same size and under the same conditions as to size and preparation of specimens and duration of tests. The tension-specimens were $1\frac{1}{2}$ inches in diameter and 10 inches long under gauge. Compression-specimens were 2 inches square and $2\frac{1}{4}$ feet long under gauge. The transverse specimens were 2 inches square, 2 feet long, clear span, and loaded at the centre. The results of the transverse tests have been reduced to equivalent bars of 1 inch square and 1 foot clear span, but the deflections are given in $\frac{1}{100}$ inch, without reduction. The modulus of elasticity in transverse stress has been calculated by the well-known formula, $E = \frac{w\,l^3}{4D\,b\,d^3}$, in which $E$ = modulus of elasticity,

$w$ = center load on the piece, $l$ = clear span, $b$ = breadth, $d$ = depth; and $D$ = deflection produced by $w$. While this neglects the effect of shearing stress, it is within the limits of error due to the inequality of rough castings.

The tests marked "A" were made on pieces differing from the above description. The sizes of specimens and method of testing "2A" were as above, but the material was not steel, but a superior gun-metal, perhaps containing wrought iron or steel scrap, and supplied at 6 cents per pound. "9A" were test-pieces submitted to the United States Navy Yard as samples of steel casting to be furnished for naval construction. These pieces were turned from end to end, and reduced in the centre for a length of 2 inches, the diameter of the reduced portion being 1 inch.

Omitting "2A," and taking an average of the elastics, elongation, and moduli of the tension-tests, 29,000 pounds, 9 per cent., and 24,443,000 pounds are found. With the exception of the elongation, which is low, this is equal to good iron, while either Nos. 7 or 9 furnish a material that is decidedly superior. In comparison with cast iron we here find a material that at the least calculation is three times as efficient for construction.

The results of the transverse tests are similar in character excepting that, subjected to this form of stress, the lack of ductility tells badly against the material, and, preventing the particles from accommodating themselves to the stress, causes rupture sooner than would have been anticipated from merely a consideration of the tension results. In compression the hardness and rigidity of the material make it compare still more favorably with wrought metal, especially where it is to be used under circumstances free from lateral or bending stresses. Between steel castings and cast iron, however, the comparison in compression is less favorable to the former, as in this form of stress the materials resemble each other closely.

The *bête noir* of steel castings has been the possibility, not to say probability, of blow-holes, the presence or absence of which can only certainly be ascertained by an examination of the fracture of the piece in question. Still, if a maker has succeeded in producing sound castings of a good quality, the presumption is that the operation can be repeated. The description of a steel fracture is a difficult piece of literature, for words can hardly convey the impression that the practiced eye at once receives, and so I have had the ends of the tension and transverse test-pieces cut off, and have brought them here to let them speak for themselves. An examination of the

specimens will show that only three of the makers have supplied samples from which both the tension and transverse pieces show perfectly sound fractures, free from blow-holes, viz., Nos. 3, 7, and 10. All the other samples are imperfect, either through the presence of blow-holes or from a soft and spongy center. Sample No. 1 shows a great want of uniformity between the fracture of the transverse and tension pieces. The transverse piece presents a fracture light in color, finely crystalline, with high metallic luster, and perfectly sound, excepting a small pipe in the center. The tension piece, on the contrary, is very dull in color, with a foliated rather than a crystalline structure, with numerous blow-holes around the periphery. Indeed, the difference between these two specimens is so great as to give rise to the suspicion, at least, that they were not cast from the same run of metal. Specimen No. 2A simply presents the ordinary cast-iron fracture. No. 3 is, perhaps, the most interesting of the collection. The castings seem to have been subjected to a process of cementation, whereby an outer coating of steel about $\frac{1}{8}$ inch thick has been formed around a center of totally different physical properties. It is probable that anything affecting this exterior skin would materially alter the value of the casting. The remainder of the samples present in their fractures little that is noteworthy, all being bright crystalline, of various degrees of fineness and metallic luster, Nos. 6 and 9 only being seriously affected by blow-holes.

The economic value of steel castings is a matter so largely dependent upon the circumstances of each particular case that a generic statement is hardly possible. Where a large number of similar castings are required, the cost of the pattern, unless exceedingly complicated, is too small to affect the price of the product, which may be generally stated at about 11 cents per pound. Where but a single casting is required, the cost of the pattern will increase that of the casting from 10 to 50 per cent. Thus it may be safely assumed that the net cost of steel castings as they come from the sand will rarely exceed 15 cents per pound unless the articles are very small and light. This is about 30 per cent. higher than the usual prices for iron and steel forgings. Yet for shapes that are at all complicated the steel casting is much the more economical, inasmuch as there is little or no waste metal, nor is any expensive machine work required to dress the rough hammered piece to its appropriate shape. Therefore, for parts of machinery that are subjected to anything but direct compression the steel casting may be,

as at present made, considered the successful rival of forged work. Where, however, compression is alone to be resisted, cast iron will for a long time to come hold its own, for, subjected to this stress, the steel is but little superior to the iron, and the great difference in price will long continue to make iron the successful competitor.

## Discussion.

Francis Collingwood, New York City: The subject treated by Mr. Abbott is one that has occupied the attention of foreign engineers for some time, and it may be of interest to review some of the results thus far obtained, more especially as they seem to be more favorable than those obtained here. Mr. William Parker, chief engineer of Lloyds, states that stern-frames, rudders, and stem-pieces of ships, also crank-shafts up to 8 tons weight, and a gun carriage 28 tons in rough and 17 tons finished, have been cast in steel, and are giving entire satisfaction, also locomotive axles. Great stress is laid by French engineers on the necessity for prompt removal from the moulds and annealing and tempering in oil after removal. A test of a casting unannealed gave a tensile strength of 32 tons and 16 per cent. stretch; when annealed, $33\frac{7}{10}$ tons and 17 per cent.; and when tempered in oil, $38\frac{6}{10}$ tons and 17 per cent. The tests by torsion, extension, transverse strains, percussion, rolling and hammering, and drop tests, all gave more favorable results than the same on wrought iron. Transverse tests of rough bars cast 1 inch square gave a strain in exterior fibers of 53,000 to 85,000 pounds per square inch, and while tempered in oil 102,000 pounds, and, after planing, similar bars bent 90° to 100° before failure. It is claimed that for large masses hammering does no good, as it does not reach to the interior, and for this reason large shafts, etc., are just as likely to be sound when cast directly as when forged. Failures which have taken place, it is claimed, can all be traced to a lack of the precautions necessary for sound work. A recent paper describes a method of making castings from wrought-iron scrap, which has been very successful. The result when best Swedish scrap was used was to increase the strength of the iron about 20 per cent., and to diminish the elongation about 5 per cent. The iron is cast at a high temperature, and the moulds are specially prepared.

## *THE HOMOGENEITY OF OPEN-HEARTH STEEL.*

BY H. H. CAMPBELL, STEELTON, PA.

In the extending employment of open-hearth steel for structural purposes, it is a matter of prime importance that the test-piece shall represent with practical accuracy the characteristics of every portion of the heat from which it comes.

In ordinary practice this homogeneity is assumed; but inasmuch as leading exponents of the revolving-hearth system have claimed that a reasonable uniformity could be obtained by their method alone, it may be pertinent to offer a few facts on the subject.

The following heats made by the Pennsylvania Steel Company, for bridge-work, were tested by casting two four-inch ingots, one being taken during the first third and the other during the last third of the cast.

Test-pieces obtained from these small ingots usually give results inferior to those obtained from larger sizes; but for purposes of comparison they are equally conclusive. Many of the tests were made for experimental purposes within a few hours of the time of rolling, and before sufficient time had elapsed for the usual molecular redistribution necessary for the best results. All the tests were made on $\frac{3}{4}$-inch rounds just as they left the rolls and without annealing; the results, therefore, are subject to the errors caused by variations in the diameter, and in the temperature at which the bar was finished.

The tests from any one heat, however, were always made as nearly as possible under the same conditions; and inasmuch as these data include the results of every heat so tested, and inasmuch as the errors could not by any chance always support any single theory, we may be certain that the unanimous testimony of the experiments indicates a valid conclusion.

*Tests from Four-Inch Ingots.*

| | Size ingot. | Average diameter of test-bar. | Elastic limit in lbs. per sq. inch. | Maximum strength in lbs. per sq. in. | Elongation in 8 inches. | Reduction of area at point of fracture. | C. | Mn. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Per cent. | Per cent. | | |
| 4718 | A 4 in. sq. | .747 | 51,790 | 70,950 | 23.75 | 38.68 | 0.21 | 0.72 |
| | B 4 " | .747 | 46,310 | 69,240 | 24.50 | 41 37 | | |
| 4720 | A 4 " | .751 | 46,160 | 71,900 | 22.50 | 40.16 | 0.21 | 0.65 |
| | B 4 " | .755 | 46,790 | 70,800 | 25.00 | 46.93 | | |
| 4721 | A 4 " | .743 | 42,200 | 67,110 | 25.00 | 42.80 | 0.21 | 0.70 |
| | B 4 " | .743 | 42,900 | 66,880 | 24.25 | 44.20 | | |
| 4722 | A 4 " | .745 | 48,510 | 68,910 | 23.75 | 45.50 | 0.20 | 0.78 |
| | B 4 " | .745 | 45,540 | 67,900 | 23.75 | 47.20 | | |
| 4724 | A 4 " | .747 | 50,070 | 71,520 | 26.25 | 42.10 | 0.22 | 0.78 |
| | B 4 " | .746 | 47,060 | 70,220 | 25.00 | 42.50 | | |
| 4730 | A 4 " | .757 | 48,430 | 71,560 | 22.75 | 37.20 | 0.20 | 0.74 |
| | B 4 " | .754 | 43,500 | 68,600 | 22.50 | 41.20 | | |
| 4731 | A 4 " | .760 | 47,400 | 70,980 | 20.75 | 36.00 | 0.20 | 0.68 |
| | A 4 " | .758 | 47,060 | 70,190 | 21.50 | 34.20 | | |
| | B 4 " | .756 | 46,350 | 70,120 | 22.75 | 36.80 | | |
| | B 4 " | .757 | 46,280 | 70,190 | 22.50 | 38.00 | | |
| 4732 | A 4 " | .756 | 44,990 | 70,320 | 23.75 | 36.40 | 0.20 | 0.72 |
| | A 4 " | .754 | 45,910 | 70,800 | 22.50 | 38.80 | | |
| | B 4 " | .756 | 44,950 | 69,700 | 21.25 | 34.90 | | |
| | B 4 " | .755 | 45,750 | 69,580 | 21.25 | 34.70 | | |
| 4733 | A 4 " | .756 | 46,220 | 70,720 | 22.50 | 41.10 | 0.20 | 0.58 |
| | A 4 " | .757 | 46,350 | 70,320 | 24.50 | 40.70 | | |
| | B 4 " | .756 | 45,820 | 70,230 | 22.50 | 39.73 | | |
| | B 4 " | .758 | 45,200 | 69,460 | 23.75 | 40.66 | | |
| 4737 | A 4 " | .754 | 45,200 | 64,100 | 25.00 | 44.05 | 0.19 | 0.42 |
| | A 4 " | .755 | 45,164 | 64,060 | 25.00 | 47.50 | | |
| | B 4 " | .755 | 47,570 | 64,880 | 22.50 | 40.00 | | |
| | B 4 " | .754 | 47,590 | 65,060 | 21.50 | 44.00 | | |
| 4738 | A 4 " | .753 | 47,020 | 69,160 | 25.00 | 48.00 | 0.19 | 0.74 |
| | A 4 " | .755 | 47,290 | 68,300 | 25.00 | 46.90 | | |
| | B 4 " | .756 | 45,550 | 68,120 | 25.50 | 47.90 | | |
| | B 4 " | .754 | 46,140 | 69,210 | 24.00 | 48.90 | | |
| 4740 | A 4 " | .744 | 44,050 | 67,860 | 22.50 | 36.40 | 0.19 | 0.58 |
| | A 4 " | .746 | 43,700 | 67,780 | 22.75 | 38.00 | | |
| | B 4 " | .745 | 43,700 | 67,200 | 22.50 | 43.60 | | |
| | B 4 " | .745 | 43,130 | 66,360 | 21.75 | 41.07 | | |

NOTE.—Where four results are given for one heat, duplicate tests were made from each ingot. In every case A is the first ingot cast and B the second.

The bars were chosen without distinction from charges of all temperatures and characteristics and with no precautions beyond those invariably taken to insure homogeneity. In addition to these tests we have more complete knowledge of two heats which were tested by a bridge-inspector for his personal satisfaction. They were selected at random by him without consultation with any one, or knowledge of their previous history.

From heat No. 4533 were cast:

One ingot 14″ square, weight 2800 lbs.

Eleven ingots 18″ x 20″, weight 3800 lbs. each.

From heat 4536 were cast:

Seven ingots 14″ square, weight 2800 lbs. each.

Seven ingots 18″ x 20″, weight 3700 lbs. each.

In heat No. 4533 a test was taken from nine of the 20-inch ingots and also from the 14-inch ingot.

In heat No. 4536 a test was taken from six of the 20-inch ingots and also from a 14-inch ingot.

Two tests were cut from each bar and the following results obtained:

*Tests from Large Ingots.*

| | Size of ingot. | Average diameter of test-bar. | Elastic limit in lbs. per sq. in. | Maximum strength in lbs. per sq. in. | Elongation in 8 inches. | Reduction of area at point of fracture. | C. | Mn. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Per cent. | Per cent. | | | |
| 4533–1 | 14 in. sq. | .740 | 51,660 | 82,000 | 22 00 | 45.15 | 0.35 | 0.83 | 1st ingot. |
| 2 | " | .737 | 52,530 | 82,980 | 23.00 | 45.30 | ..... | ..... | |
| 3 | 18 x 20 in. | .754 | 51,390 | 81,340 | 23 50 | 48.70 | ..... | ..... | 2d " |
| 4 | " | .755 | 51,470 | 81,300 | 23.70 | 46.00 | ..... | ..... | |
| 5 | " | .753 | 49,270 | 80,800 | 25.00 | 54.10 | ..... | ..... | 3d " |
| 6 | " | .752 | 49,630 | 81,360 | 25.70 | 54.90 | ..... | ..... | |
| 7 | " | .750 | 51,380 | 84,240 | 24.70 | 52.40 | ..... | ..... | 4th " |
| 8 | " | .753 | 51,970 | 83,200 | 24.00 | 52.30 | ..... | ..... | |
| 9 | " | .752 | 48,820 | 83,660 | 23.00 | 44.50 | ..... | ..... | 5th " |
| 10 | " | .751 | 50,780 | 84,420 | 22.50 | 41.40 | ..... | ..... | |
| 11 | " | .753 | 51,930 | 83,760 | 23.50 | 45.00 | ..... | ..... | 6th " |
| 12 | " | .753 | 50,700 | 84,200 | 22.30 | 49.50 | ..... | ..... | |
| 13 | " | .755 | 54,210 | 83,760 | 22.70 | 43.60 | ..... | ..... | 7th " |
| 14 | " | .755 | 55,270 | 84,640 | 22.80 | 46.90 | ..... | ..... | |
| 15 | " | .754 | 49,500 | 81,240 | 22.70 | 48.60 | ..... | ..... | 8th " |
| 16 | " | .756 | 51,110 | 82,080 | 24.90 | 50.00 | ..... | ..... | |
| 17 | " | .750 | 50,200 | 81,760 | 24.80 | 48.30 | ..... | ..... | 9th " |
| 18 | " | .751 | 51,190 | 82,480 | 23 30 | 48.30 | ..... | ..... | |
| 19 | " | .753 | 49,130 | 82,560 | 22.70 | 46.20 | ..... | ..... | 10th " |
| 20 | " | .753 | 50,960 | 82,460 | 22.30 | 44.70 | ..... | ..... | |
| 4536–1 | 14 in. sq. | .737 | 50,570 | 75,710 | 25 25 | 52.70 | 0 23 | 0.89 | 1st ingot. |
| 2 | " | .733 | 51,310 | 76,300 | 25.00 | 50.10 | ..... | ..... | |
| 3 | 18 x 20 in. | .754 | 54,860 | 78,770 | 25.10 | 56.00 | ..... | ..... | 2d " |
| 4 | " | .753 | 55,670 | 78,810 | 24 60 | 57.60 | ..... | ..... | |
| 5 | " | .753 | 50,750 | 76,730 | 25.20 | 54.10 | ..... | ..... | 3d " |
| 6 | " | .752 | 50,870 | 76,860 | 23.90 | 54.00 | ..... | ..... | |
| 7 | " | .754 | 54,100 | 76,220 | 26.20 | 53.40 | ..... | ..... | 4th " |
| 8 | " | .752 | 49,700 | 77,230 | 25.00 | 54.00 | ..... | ..... | |
| 9 | " | .753 | 48,450 | 77,280 | 24.20 | 56.70 | ..... | ..... | 5th " |
| 10 | " | .750 | 48,780 | 78,090 | 25.70 | 57.30 | ..... | ..... | |
| 11 | " | .752 | 47,740 | 74,180 | 27.00 | 54.50 | ..... | ..... | 6th " |
| 12 | " | .752 | 47,520 | 74,490 | 26.20 | 54.60 | ..... | ..... | |
| 13 | " | .751 | 50,600 | 78,820 | 23.90 | 49.40 | ..... | ..... | 7th " |
| 14 | " | .752 | 51,650 | 79,050 | 25.00 | 46.30 | ..... | ..... | |

The bars were prepared in the same manner as those of the first table, and the remarks concerning sources of error are equally pertinent, as may be seen by the following application:

It is the general law that, other things being equal, as the strength-columns (elastic limit and maximum strength) augment, the ductility-columns (elongation and contraction of area) decrease, and *vice versa*.

But in the tables above, it will be found that in neither heat is the maximum in the strength-columns coincident with the minimum in the ductility-columns; neither is the minimum of the first coincident with the maximum of the latter.

We may, however, obliterate the influence of individual irregularities by forming, in each heat, groups of the bars giving low ultimate strengths and those giving high results, and we will find that the results accord with the law, and indicate the true formula of the heat.

An inspection of the table will justify this division as not entirely arbitrary.

Heat No. 4533 { Group I., bars 3, 4, 5, 6 and 15.
Group II., bars 7, 10, 12 and 14.

The averages of these are as follows:

| | Elastic limit. | Maximum strength. | Elongation. | Reduction of area. |
|---|---|---|---|---|
| Group I., | 50,252 | 81,210 | 24.12 | 50.46 |
| Group II., | 52,032 | 84,375 | 23.08 | 47.55 |

Similarly,

Heat No. 4536 { Group I., bars 5, 6, 7, 11 and 12,
Group I., bars 3, 4, 10, 13 and 14,

gives the following analysis:

| | Elastic limit. | Maximum strength. | Elongation. | Reduction of area. |
|---|---|---|---|---|
| Group I., | 50,196 | 75,696 | 25.70 | 54.12 |
| Group II., | 52,312 | 78,708 | 24.86 | 53.32 |

These results more nearly represent the true character of the metal than those obtained from the 4-inch ingots under the various conditions before mentioned.

A slight superiority may be detected in the bars rolled from 20-inch ingots over those obtained from the 14-inch; but a conclusion drawn from these two cases would be puerile. We may, however, confidently assert, from the comparative figures of the first table and the more definite results of the second, that the assumption of homo-

geneity in a heat of steel made, with proper care, in a stationary open-hearth, involves no errors that are not entirely overshadowed by the inevitable irregularities incident to practical construction.

---

## *THE WORK OF THE BLAST-FURNACES OF THE NORTH CHICAGO ROLLING-MILL CO.*

BY FRED. W. GORDON, PHILADELPHIA, PA.

THE North Chicago Rolling-Mill Co., of Chicago, have four furnaces at South Chicago, built during 1881. Each furnace is 20 feet diameter of bosh, and 75 feet total height, the hearth being 11 feet diameter, and the top 15 feet 4 inches. They are blown through seven 7-inch tuyeres placed 5 feet 6 inches above the hearth level. Cubical contents, 15,000 cubic feet. Each furnace is supplied with 2 blowing engines, 84-inch blowing cylinder, and 36-inch steam cylinder, and 54-inch stroke. These two have one jet-condenser worked by an auxiliary pump. The blast for each furnace is heated by the aid of three Whitwell fire-brick stoves, each 21 feet diameter and 60 feet high. In the batteries of boilers furnishing steam for four furnaces there are 36 double-length boilers, 72 feet long, 48 inches diameter and 16,000 square feet heating-surface.

The plant was designed to produce 3600 tons per week, or 900 tons for each furnace, and was fitted as above with such engines, boilers, and hot-blast stoves as were thought requisite for that production; hence, calculated from the present make—not the least remarkable feature is the economy of construction—there are less engines, less boilers, and less hot-blast power for the iron made than at any plant within my knowledge, or it could to-day be duplicated for less money per ton of iron made per week than could any plant now in existence, whether using fire-brick or cast-iron stoves for heating the blast. This is a practical demonstration of my assertion in a paper on fire-brick stoves, read before the Institute,* that the application of fire-brick stoves in construction really lessens the first cost.

In view of the statements just made, I must be most emphatic in assuring the members that nothing is strained or overburdened.

---

* *Transactions*, vol. ix., p. 488.

The engines run at 28 revolutions, the piston speed being 252 feet per minute. The hot-blast stoves at present heating the blast to 1450° F. have ample power to sustain the heat, and the boilers, which are now all on for three furnaces, are continually blowing off steam without any extra attention. The surplus of steam generated is so great that no thought of difficulty can be entertained when the fourth furnace is put on. As for the engines and stoves, there are only those used which belong strictly to the plant at work. With the four furnaces at work at the present average there will be but 21 feet of boiler surface per ton of iron per 24 hours. One 84-inch engine is furnishing blast for over 100 tons of iron per day, and 350 square feet of surface in the stove plant are heating the blast for each ton of iron per day.

After a blast with each of the original furnaces, which was not entirely satisfactory, they were remodeled to the writer's designs, and No. 5 started March 22, 1884. The work was most satisfactory, compared with the best work at that time, and the remodeling of Nos. 6, 7, and 8 was proceeded with, all being built exactly alike. No. 8 has not been blown in, but is ready. The large make of the others and the slack orders are the reasons. No. 6 was blown in July 28, 1884, and No. 7 March 31, 1885. The latest monthly reports of these furnaces are:

| Month. | Total tons, 2240 lbs. | Pounds of coke per ton (2240 lbs.) of iron. | | |
|---|---|---|---|---|
| | | No. 5. | No. 6. | No. 7. |
| May | 15,063 | 2,236 | 2,198 | 2,182 |
| June | 17,539 | 2,155 | 2,130 | 2,190 |
| July | 17,166 | 2,127 | 2,105 | 2,012 |
| August | 16,955 | 1,967 | 1,994 | 1,875 |

During August there was an unusual stoppage of 57 hours, owing to delays in the mill. As the metal from these furnaces is worked direct in the converters, the furnaces and the mill are worked together as much as possible.

For the last four weeks the pounds of coke per ton of iron on No. 7 were:

1,930 1,833 1,800 1,875

The fuel was the ordinary Connellsville coke, its analysis being:

| | Ash. | Sulph. | Carbon. | Vol. matter, and moist. |
|---|---|---|---|---|
| Week ending July 4, . . | 14.95 | 0.85 | 83 25 | . . . |
| Week ending July 11, . . | 11.23 | 0.92 | 86.90 | . . . |
| Week ending July 18, . . | 11.43 | 0.89 | 86.73 | . . . |
| Week ending July 25, . . | 10.65 | 0.77 | 87.63 | . . . |
| Week ending August 1, . | 11.60 | 0.64 | 86.81 | . . . |
| Week ending August 8, . | 9.88 | 0.92 | 88.25 | . . . |
| Week ending August 15, . | 11.51 | 0.94 | 86.60 | . . . |
| Average, . . . | 11.61 | 0.85 | 86 57 | 0.95 |

The charges of No. 7 consisted of:

| Pounds. | Ores. | $Fe_2O_3$. | $SiO_2$. | $Al_2O_3$. | CaO. | MgO. | Vol. | $P_2O_5$. |
|---|---|---|---|---|---|---|---|---|
| 3,000 | Chapin..... | 89.92 | 5.86 | 2.68 | 0.36 | 0.04 | 0.98 | 0.105 |
| 2,000 | Cleveland specular. | 93.25 | 3.00 | 1.65 | 0.41 | 0.18 | ... | 0.200 |
| 1,000 | Cleveland hematite | 85.84 | 7.10 | 3.03 | 0.58 | 0.20 | 2.34 | 0.076 |
| 2,000 | Ludington..... | 91.98 | 3.82 | 2.87 | 0.39 | 0.51 | ... | 0.080 |
| 2,000 | Norrie..... | 87.10 | 7.20 | 2.31 | 0.40 | 0.15 | ... | 0.113 |
| 1,000 | Summit..... | 90.41 | 4.39 | 3.30 | 0.89 | 0.16 | ... | 0.230 |
| 1,000 | Superior hematite.. | 85.80 | 5.06 | 4.855 | 1.35 | 1.39 | ... | 0.162 |
| | Average..... | 89.70 | 5.18 | 2.74 | 0.52 | 0.30 | ... | 0.131 |

| | Per cent. |
|---|---|
| Metallic iron, . . . . . | 62.790 |
| Phosphorus, . . . . . | 0.057 |
| Earths, . . . . . | 8.740 |

The yield from the ore in the furnaces was, however, only 63 per cent., while the pig contained 2 per cent. of silicon and 4 per cent. of carbon. The metallic iron in the ore would thus be but 59.22 per cent., so that the earths would be $8.74 - 2.68\ SiO_2 = 6.06$, to which the supposed iron of the analysis $(62.79 - 59.22)$ should be added, equal to $6.06 + 3.57 = 9.63$ per cent., allowing for the silicon of the pig coming from the ore.

During the last four weeks the charge on No. 7 has averaged to each ton of 2240 pounds of pig iron:

| | | |
|---|---|---|
| Ore, . . . | 3555.5 | pounds containing 2105 pounds iron. |
| Fuel, . . . | 1862 | pounds containing 1612 pounds carbon. |
| Flux, . . . | 608 | pounds containing 553 pounds limestone. |

The waste gas analysis and temperature were taken repeatedly and carefully, and averaged 46 volumes of carbonic acid to 100 volumes of carbonic oxide. The temperature of the waste gases was 480° F., while the blast temperature was 1375° F.:

| | |
|---|---|
| The average make for 24 hours' running time was, tons, | 209 |
| The average make for week, running time, was, tons, | 1463 |
| Product per week per 1000 cubic feet furnace capacity, tons, | 97.5 |
| Average total engine revolutions, per minute, | 56 |
| Average time in motion per day, hours, | 22 |
| Displacement of piston each revolution, cubic feet, | 345 |
| Pressure of blast in engine-room, pounds per square inch, | 6 |
| Pressure of blast at tuyere, pounds per square inch, | 4 |
| Work done by blowing engines, horse-power, | 507.8 |
| Work done by blowing engines per ton in 24 hours, horse-power, | 2.44 |
| Add 50 per cent. to this for hoisting and pumping and total per ton, 24 hours, horse-power, | 3.66 |
| Heating surface of boilers apportioned to each furnace per horse-power developed square feet, | 5.25 |

The work of this furnace is here analyzed by Sir I. Lowthian Bell's system (see *Chemical Phenomena of Iron Smelting*, page 154, etc.), using his cwt.-units, etc., that it may be more easily compared with European data:

*Composition of the Waste Gases.*

| | By vol. | By weight. | Carbon. | Oxygen. |
|---|---|---|---|---|
| Carbonic acid, | 12.88 | 18.85 | 5.142 | 13.712 |
| Carbonic oxide, | 28.00 | 26.08 | 11.178 | 14.904 |
| Nitrogen, | 59.12 | 55.06 | ... | ... |
| Total, | 100.00 | 99.99 | 16.320 | 28.616 |

| | | |
|---|---|---|
| Coke used, cwts. per 20 cwt. of iron, | | 16.62 |
| Carbon in coke, | 14.39 | |
| Less carbon in limestone, | 0.57 | Total carbon. cwt., 14.96 |
| Leaving carbon burned to CO, | 13.82 | |

*Heat Produced by Combustion of* 13.82 *cwts. C.*

| | |
|---|---|
| Carbonic oxide, $13.82 \times 2400 =$ | 33,168 |
| Carbon of this carbonic oxide burned to carbonic acid, 14.16* $\times$ 5.142, divided by 16.32, equal to $4.46 \times 5600 =$ | 24,976 |
| Total cwt.-heat-units from combustion of carbon per gross ton of iron produced, | 58,144 |

*Gases per Ton of Pig Iron.*

| | | | C. | O. |
|---|---|---|---|---|
| Nitrogen in gases, | 16.32 : 14.16 : : 55.06 | = 47.73 | | |
| Carbonic oxide, | 16.32 : 14.16 : : 26.08 | = 22.62 | 9.70 | 12.92 |
| Carbonic acid, | 16.32 : 14.16 : : 18.85 | = 16.36 | 4.46 | 11.90 |
| Total cwts. per gross ton of pig-iron, | | 86.71 | 14.16 | 24.82 |

* This is the total weight of carbon, 14.96, less 0.8 carbon in the ton of pig.

*Weight of the blast:*

| | |
|---|---|
| Nitrogen as before, | 47.73 |
| Oxygen with it, | 14.40 |
| Moisture, | 0.50 |
| Total cwts. per gross ton of pig-iron, | 62.63 |

*Oxygen furnished by the ore:*

| | |
|---|---|
| Oxygen that was associated with 18.8 Fe, | 8.060 |
| Oxygen that was associated with 0.02 P, | 0.026 |
| Oxygen that was associated with 0.04 Si, | 0.460 |
| Total cwts. per gross ton of pig-iron, | 8.546 |

We can now check the results of gas-analyses by the following calculation:

| | |
|---|---|
| Oxygen brought in by the blast, | 14.40 |
| Oxygen brought in by the moisture, | 0.44 |
| Oxygen brought in by the ores, | 8.546 |
| Oxygen brought in by the limestone, | 1.52 |
| Total, | 24.906 |
| Oxygen in the gases by analysis, | 24.820 |
| Difference, | 0.086 |

*Gains and Losses of Heat.*

The total heat developed is as follows:

Heat contributed by the blast, which had a temperature of 1375° F. = 746° Celsius: $62.63 \times 746 \times 0.237 = 11{,}073$ cwt.-heat-units.

Heat developed from combustion of carbon, 58,144.

Heat lost by the gases: $86.71 \times 249 \times 0.24 = 5181$ cwt.-heat-units.

| *Heat accounted for:* | Cwt.-units |
|---|---|
| 18.8 iron from $Fe_2O_3$, absorbing 1780 calories each unit, | 33,464 |
| Carbon impregnation, $0.8 \times 2400$, | 1,920 |
| Dissociation of phosphorus and silicon from their oxygen, | 3,360 |
| Fusion of pig, | 6,600 |
| Transmission through wall (Bell's estimate) | 5,476 |
| Total constant requirements, | 50,820 |
| Evaporation of water in coke, | 324 |
| Expulsion of carbonic acid from limestone, $4.76 \times 370$, | 1,761 |
| Decomposition of carbonic acid from limestone, $0.57 \times 3200$, | 1,824 |
| Decomposition of water in blast, $0.055 \times 34{,}000$, | 1,870 |
| Fusion of slag, $9.27 \times 550$, | 5,098 |
| Carried off in waste gases, as above, | 5,181 |
| Expansion of the blast, | 2,350 |
| Total, | 69,328 |
| Heat developed as above, | 69,217 |
| Difference, | 111 |

It seems that the following debatable propositions are at least more nearly settled by this work:

1. Strict economy in fuel consumption can be effected, while the product is very great.

2. In accompanying this great output by lowering the heat-units employed to a unit of work, the temperatures throughout the furnace are lowered (except perhaps at the immediate region of the tuyeres), and thereby greater durability of the walls secured. In the vicinity of the tuyeres are placed well-tried appliances to combat the erosion accompanying this intense local temperature.

3. By proper construction and practice, the region of economic reduction has been so far increased that the gases pass away at an exceedingly low temperature, while they contain a maximum of carbonic acid as compared with any mineral fuel practice, though flowing with rapidity.

4. The reduction of fuel consumption having been accompanied with increased output, while engine-speed, and pressure, and steam consumption have been reduced, the cost of plant per unit of product does not represent so great an outlay, while the parts are not driven so fast.

5. As out of 69,217 heat-units developed, 11,073 come in with the blast, much of the economy must be credited to superheated blast, independent of the changed condition of the descending material tending toward further economy in part resulting from this heat.

Inasmuch as from April till the present time, no change whatever has been made in the furnaces or their appliances, an examination of what a furnace may be doing is no criterion of what it should do in fuel-economy. The examination by Sir I. Lowthian Bell and others of furnaces to which superheated blast has been applied, is only of existing facts and not of the possibilities. I maintain from this experience that such practice as should have accompanied the increase of blast heat was not resorted to; hence but little economy was found to follow. If with a given consumption of fuel, 1000° F. in the blast sufficed for all the heat requirements, any additional heat introduced in the blast must be found in the escaping gases, or the proportion of carbonic acid will be reduced, or both. This is what examinations have shown, but they have not shown that the fuel could not be saved. It is hoped that the record given does establish that it can. Below I calculate the fuel consumption required when using similar material to that used at the Durham Furnace, as given in B. F. Fackenthal Jr.'s carefully prepared paper read at the late Chattanooga meeting. The

work of this furnace is perhaps as good as any under similar conditions.

It has good height to absorb the heats, has good regular heats in the blast, and the contrast seems as favorable to the cast-iron stove practice as its most ardent advocates could wish. The only change I have made from the charges in Mr. Fackenthal's paper is a small reduction in the limestone required to meet the reduction of fuel ash. The fuel is calculated at the same percentage of carbon, and it is assumed that the gases may be made to pass away containing as large a percentage of carbonic acid and at as low a temperature. These two latter propositions may not be admitted, but comparative data* and reasoning on the subject would lead to the conclusion that more carbonic acid† and a lower temperature might be found‡ where the larger quantity of limestone is used.

In the calculation just made 69,217 heat units were developed from 16.62 cwt. of fuel, or for each hundredweight of fuel 4160 heat units. If the unit requirements in the new case are divided by this

---

* Sir I. L. Bell gives the Clarence and Ormsby furnaces and two Consett furnaces as follows:

| | Blast-heat. | Limestone, cwt. | Carbon in coke. | Carbon in carbonic acid of gases. | Carbon of the carbonic acid of the gases divided by carbon of the fuel. |
|---|---|---|---|---|---|
| Clarence..... | 485° C. | 13.66 | 20.40 | 6.52 | } 31.85 |
| Ormsby..... | 780° C. | 12.50 | 20.34 | 5.45 | |
| Consett..... | 454½° C. | 8.50 | 20.71 | 5.11 | } 28.00 |
| Consett..... | 718° C. | 8.12 | 16.38 | 4.75 | |

Showing that the furnaces more heavily charged with limestone had the largest quantity of carbonic acid as compared to the fuel consumed. These cases I take as fairly good examples, as the examination does not reveal any marked degree of economy of the former pair over the latter, all conditions considered.

† Carbonate of lime commences to lose its carbonic acid at a low red heat; much more rapidly than that carbonic acid will be converted into carbonic oxide in the presence of coke. From this it is inferred that some of the carbonic acid of the limestone is found in the gases without suffering any conversion.

‡ All of this carbonic acid converted into 2 carbonic oxide absorbs 3200 calories of heat per unit of carbon in the carbonic acid. Hence it follows that the greater the gas of the limestone is in proportion to the total gases the cooler will the latter be in passing from the furnace, as much of the carbonic acid is converted into 2 carbonic oxide. And I would say that the practice being the same with the Durham Furnace and South Chicago materials, to assume the gases in an equally economical condition with the former is understanding the probabilities.

number, the quotient will be the approximate hundredweight of coke required. Let us arrive as closely as can be at what the requirements are:

*Heat Units Approximated when Using Durham Materials, Conditions being similar to those at South Chicago.*

| | |
|---|---|
| Constant requirements, as before, | 50,820 |
| Evaporation of water of coke, say, | 100 |
| Expulsion of carbonic acid from limestone, $20 \times 370$, | 7,400 |
| Decomposition of carbonic acid from limestone, $2.18 \times 3200$, | 6,976 |
| Decomposition of water of blast, $0.1 \times 34{,}000$, | 3,400 |
| Fusion of slag, $20 \times 550$, | 11,000 |
| Carried off by gases, say, | 8,000 |
| Expansion of blast, | 3,000 |
| Total, | 90,696 |

$90{,}696 \div 4160 = 21.8$ cwt. of fuel required (approximately); but 21 cwt. will probably suffice, as the following calculation will establish:

| | | | |
|---|---|---|---|
| Hundredweights of fuel required, | | | 21.00 |
| Less ash, | | | 2.82 |
| Carbon, | | | 18.18 |

*Gases as before by weight:*

| | Carbon. | Oxygen. |
|---|---|---|
| Carbonic acid, 18.85, | 5.142 | 13.712 |
| Carbonic oxide, 26.08, | 11.178 | 14.904 |
| Nitrogen, 55.06, | — | — |
| Total, | 16.32 | 28.616 |

Coke used, 21.00

| | | | |
|---|---|---|---|
| Carbon in coke, | 18.18 | Total carbon, | 20.36 |
| Less carbon in limestone, | 2.18 | | |
| Leaves carbon burned to carbonic oxide, | 16.00 | | |
| $16.00 \times 2400 =$ | | | 38,400 |
| Carbon of this carbonic oxide burned to carbonic acid, $19.76 \times 5.142 \div 16.32 = 6.22 \times 5600 =$ | | | 34,832 |
| Total, | | | 73,232 |

*Gases, weight per 20 cwt. of pig iron:*

| | |
|---|---|
| Total carbon, | 20.36 |
| Less carbon of pig, | 0.60 |
| | 19.76 |

| | | Carbon. | Oxygen. |
|---|---|---|---|
| Nitrogen, . . | 16.32 : 19.76 : : 55.06 = 66 66 | | |
| Carbonic oxide, . | 16.32 : 19 76 : : 26 08 = 31.57 | 13.53 | 18.04 |
| Carbonic acid, . | 16.32 : 19.76 : : 18.85 = 22.83 | 6.23 | 16.60 |
| Water in coke, etc., . . . . . | 0.40 | — | — |
| Total, . . . . . | 121.46 | 19.76 | 34.64 |

*Weight of the blast:*

| | |
|---|---|
| Nitrogen as above, . . . . . | 66.66 |
| Oxygen with it, . . . . . | 20.00 |
| Moisture, . . . . . | 0.40 |
| Total, . . . . . | 87.06 |
| Oxygen with the blast, . . . . . | 20.00 |
| Oxygen with the moisture, . . . . . | 0.36 |
| Oxygen with the ore, . . . . . | 8.54 |
| Oxygen with the limestone, . . . . . | 5.81 |
| Total, . . . . . | 34.71 |
| Oxygen with the gases, . . . . . | 34.64 |
| Difference, . . . . . | 0.07 |
| Heat contributed by the blast, $87.06 \times 746 \times 0.237 =$ . . | 15,392 |
| Add heat by combustion of the carbon, . . . . . | 73,232 |
| Total, . . . . . | 88,624 |
| Heat carried off by the gases, $121.46 \times 249 \times 0.24 =$ . . | 7,258 |
| Assumed units required, . . . . . | 90,696 |
| Less $8000 - 7258 =$ . . . . . 742 | |
| Less for silicon in the pig, 3360 ÷ 3 (estimated from description of pig), . . . . . 1120 | |
| | 1,862 |
| Total, . . . . . | 88,834 |
| Heat furnished, . . . . . | 88,624 |
| Difference, . . . . . | 210 |

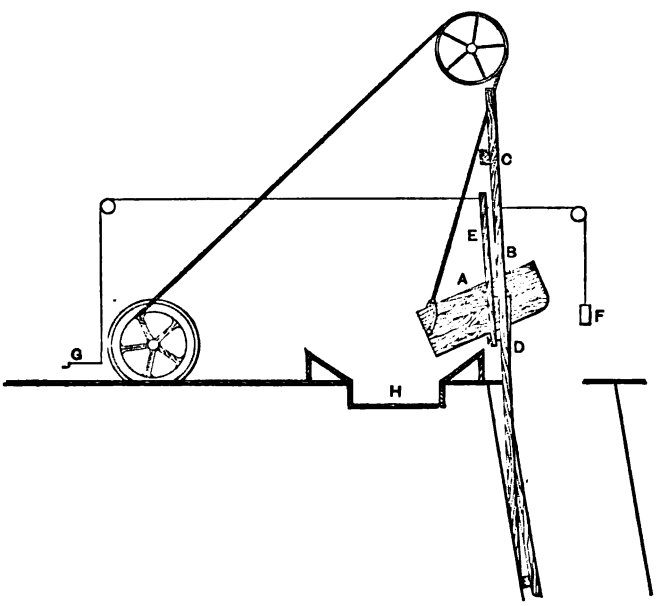
It would seem from this that the additional fuel required for the material used at the Durham as compared to that used at South Chicago is $21 - 16.62 = 4.38$ cwt., and that a reduction in consumption of fuel might be effected at the Durham of:

| | |
|---|---|
| $1.24 \times 2240 =$ . . . . . | 2777 |
| $112 \times 21 =$ . . . . . | 2352 |
| | 425 pounds of fuel. |

## *NOTE ON A SELF-DUMPING WATER-TANK.*

BY WILLARD IDE PIERCE, NEW YORK CITY.

IT is often desirable to work an old mine that has not been in operation for some time and that is filled with water. This is especially true in Nova Scotia, where no great depth has yet been reached in any of the mines. The following is a description of a self-dumping water-tank which was used by me at Tangier, for draining a mine, and which did the work of a large pump, while the original




Self-Dumping Water-Tank.

cost is merely nominal, in comparison with the price of a pump. The tank, A, Fig. 1, is $1\frac{1}{2}$ by 3 feet and 4 feet high, inside measurement, made of 2-inch stuff and securely bound with iron.

There are two clacks in the bottom which open as the tank is lowered into the water, and which close and hold the water as the tank is raised. B is an iron rod running through the tank, below and back of the center, and projecting beyond the sides of the tank. C is one of two guides, and D, a movable iron rod in each guide. This rod, attached to an upright, E, is moved forward and close up

against the guide by means of the lever, G, and, on being released, is brought back into position by the weight, F.

The tank being in the shaft and full of water is hoisted by means of a cable passing over a drum. On nearing the surface the tank passes between the guides, C (the rod, B, running over them), and is raised until the rod, B, is over the rod, D, when the tank is lowered until its weight is held by the rod, D; the cable is then slackened and the tank tips forward and discharges the water into the sluice-box, H. The tank is then raised until its weight is removed from the rod, D, when the engineer by means of the lever, G, forces the rod against the guide, C, and the tank is thus permitted to pass down into the shaft to be again filled. A tank like the above will discharge 75 gallons per minute from a depth of 150 feet, and one man only is required to operate it.

---

## *ESTIMATION OF MANGANESE, CARBON, AND PHOSPHORUS IN IRON AND STEEL.*

BY BYRON W. CHEEVER, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICH.

WHILE working upon the processes which have been described from time to time in the *Transactions* of the Institute for the estimation of these elements, I discovered that certain reactions take place under certain conditions which if overlooked, give erroneous results. Some of these reactions are new, to me at least.

### *Estimation of Manganese.*

A weighed sample is dissolved in nitric acid and the manganese precipitated by potassium chlorate in the usual manner, care being taken to add some strong nitric acid at the last, and boil, to completely destroy the chlorate. Filter through purified asbestos, suck the filter dry with an aspirator; then wash with $HNO_3$ (1.40 sp. gr.) until the acid comes through clear, and again suck dry with the aspirator. The nitric acid used for washing must be free from nitrous acid, for this acid reduces the peroxide of manganese; the lower oxide thus formed is dissolved by the strong nitric acid and is carried through the filter; some manganese also will nearly always be dissolved if the precipitate is washed with water. The nitric

acid should always be freed from nitrous acid before use by blowing air through it till perfectly colorless.

Now transfer the precipitate, with the asbestos, to the beaker in which the precipitate was formed; add 75 c. c. of water and then run in from a burette a deciuormal solution of ammonio-ferrous sulphate, 5 c. c. at a time, stirring briskly after each addition, until the $MnO_2$ is all dissolved.

The decinormal ammonio-ferrous sulphate is prepared by dissolving 39.2 grains of the salt in water, adding 50 c. c. of strong $H_2SO_4$ and then diluting with water to one liter. If heat has been employed in dissolving the $MnO_2$, the solution must be cooled and then the excess of ammonio-ferrous sulphate titrated back with decinormal potassium permanganate (made by dissolving 3.156 grms. $KMnO_4$ in one liter of water, and compared with the ammonio-ferrous sulphate before use).

The number of cubic centimeters of the ammonio-ferrous sulphate actually required to reduce the $MnO_2$, multiplied by $0.00274 = Mn$.

There is some difficulty in determining when enough permanganate has been used to oxidize the excess of ammonio-ferrous sulphate, on account of the gradual fading of the rose-color after the end-reaction has apparently been reached. This seems to be due to the manganous sulphate, which in acid solutions, when asbestos or some other insoluble matter is present, causes the rose-color to gradually disappear without destroying the oxidizing power of the solution; for after an excess of permanganate has been added and no rose-color produced, this solution, on being titrated with ammonio-ferrous sulphate, will require as much of this reagent as the excess of permanganate used. In order to overcome this difficulty and obtain accurate results, I titrate back the excess of ammonio-ferrous sulphate with the permanganate till the first flash of the rose-color is obtained, and then test a drop of the solution on a porcelain slab with a drop of freshly prepared potassium ferricyanide. If it gives a blue color, add more permanganate; if not, add a few drops of the ammonio-ferrous sulphate, to see if you have not gone too far. In this way the exact end-reaction can be obtained. After a little practice, the end-reaction can be determined without the indicator, which makes the process more rapid than when bichromate is used.

Of the other processes, the acetate and Ford's both give too high results. It seems almost impossible to thoroughly wash the acetate precipitate; and the manganese phosphate always contains either lime or magnesia, or both, which the strong HCl has dissolved from

the asbestos. Volhard's process, when properly performed, gives good results.

The colorimetric process which is quite extensively used in some sections, can never be made to give reliable results, for it is impossible with peroxide of lead and nitric acid to convert all of the manganese into permanganate, only about two-thirds being thus changed; and as the amount thus converted is not constant, it is impossible to obtain even fair working results.

### *Estimation of Carbon.*

In estimating carbon by the chromic acid method, I have found it necessary to prepare my own reagents, since those obtained from the manufacturers are often so impure as to preclude the possibility of obtaining correct results. I would therefore call especial attention to the preparation of Nos. 1 and 4 of the following reagents:

*Reagents.*—No. 1. Dry granular calcium chloride, free from calcium oxide: Take crystallized calcium chloride in a porcelain dish and heat very carefully (not above 200° C.) till fused, then stir constantly until granulated; now transfer the dish to an air-bath and heat at 200° C. till perfectly dry. Keep in well-corked bottles. After filling the U tubes, pass dry $CO_2$ for one hour, then dry air until the $CO_2$ is removed.

No. 2. Anhydrous copper sulphate: Take small pieces of pumice stone, soak them in a saturated solution of copper sulphate, and then heat them in an air-bath for several hours at 250° C.; cool and keep in well-corked bottles.

No. 3. Double chloride of copper and ammonium: Take 340 grms. $CuCl_2,2H_2O$, 214 grms. $NH_4Cl$, and 1850 c. c. water. When dissolved add enough $NH_4OH$ to form a slight precipitate; allow this to subside and use only the clear solution. Of this solution 50 c. c. will dissolve one gramme of steel.

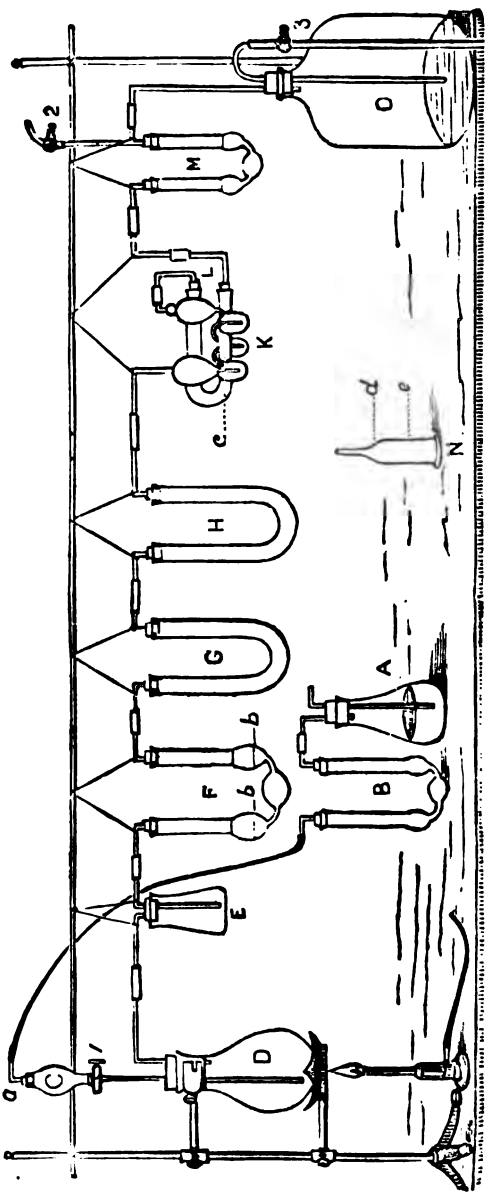
No. 4. Solution of $CrO_3$ and $H_2SO_4$: Take 16 grms. $CrO_3$ and dissolve in 100 c. c. of water in a porcelain dish; add to this 260 c. c. of strong $H_2SO_4$* and heat to incipient ebullition. When cold it is ready for use. It should not be prepared long before needed.

* On adding the $H_2SO_4$ to the $CrO_3$ solution, white fumes, with a peculiar odor, arise; these are not retained by any of the materials used in the U-tubes; therefore if the mixture is made in the generating-flask in the usual way, these fumes pass on and are absorbed by the potash in the potash-bulb, which always gives high and varying results. But by preparing the reagent as above given, this error is avoided. I have not been able to determine the nature of these fumes.

One gramme of ordinary steel will require 30 c. c. of this solution; the amount must be increased with the per cent. of carbon.

*Description of Apparatus.*—In the accompanying figure A and B are for removing $CO_2$ from the air; A is filled one-third full with a solution of KHO, and B is filled with soda-lime. C is a funnel for transmitting the solutions into the generating-flask D; it is connected by a rubber tube and cork *a* with the U-tube B, so that all the air which enters the apparatus at this end is freed from $CO_2$; it is also provided with a stop-cock (1). D is the generating-flask. E is a flask for condensing any vapor that may pass over during the operation. The bottom is covered with strong $H_2SO_4$; the entrance-tube passes just through the cork, and the exit-tube extends down to within one-quarter of an inch of the $H_2SO_4$. For greater safety this flask may be immersed in a beaker of cold water. F is an 8-inch three-bulb U-tube filled to the mark *b* with strong $H_2SO_4$. G is an 8-inch plain U-tube filled with granular calcium chloride. H is an 8-inch plain U-tube, the left arm filled with anhydrous copper sulphate, and the right arm with granular calcium chloride. K is a potash bulb filled to the mark *c* with KHO (1.27 specific gravity); connected with it, and fastened to it, is a 4-inch plain U-tube, L, the upper arm filled with soda-lime, and the lower arm with granular calcium chloride. K and L are for the absorption of the carbon dioxide. M is a guard tube, the left arm filled with granular calcium chloride, and the right with soda-lime. O is an aspirator-bottle, which holds 5 liters of water. N is a funnel tube for collecting the carbon.

*Description of the Process.*—Weigh out 3 grms. of the fine iron or steel, add 150 c. c. of the double chloride of copper and ammonium solution; stir the solution frequently, and after a few minutes apply a gentle heat (50° or 60° C.). When the iron and precipitated copper are dissolved, add a few drops of HCl to dissolve the thin film of oxide of iron, which has formed on the surface. The carbon is now collected in the funnel N, which is loosely stopped with a small quantity of asbestos. Hot water is first run through the filter, then the solution; the residue is washed once with the double chloride, and then with hot water, until the wash-water gives with $AgNO_3$ no reaction of chlorine. The funnel is then broken into three pieces, by scratching at *d* and *e* with a file and applying a hot iron, and the pieces, with the carbonaceous residue, are introduced into flask D. The whole apparatus is now carefully connected, and the aspirator set running; valves 1 and 3 being open and 2 closed,




Apparatus for the Estimation of Carbon by the Chromic Acid Method.

and 1 liter of air drawn through; valve 3 is now closed and valve 2 opened. After standing thirty minutes disconnect K and L and weigh them. Re-connect K and L, close valves 1 and 2, remove the cork, *a*, and, by means of a funnel, introduce into C 90 c. c. of the solution of $CrO_3$ and $H_2SO_4$; insert cork, *a*, open valve 3, and start the aspirator. As soon as air-bubbles commence coming through K, open valve 1 and allow the solution to flow gradually into D. Now close valve 1 and apply heat to D; shake D carefully to insure thorough contact of its contents, and continue the heat till white fumes appear, or to incipient ebullition. Remove the lamp and gradually open valve 1 till wide open; when the aspirator O is half empty, open valve 3 so that the air-bubbles will come over more rapidly. At first the bubbles should not come through faster than three in a second, and at no time fast enough to throw the potash solution in K into the exit-tube. When the aspirator O is nearly empty close valve 3, and in about five minutes open valve 2; allow the apparatus to stand thirty minutes, then disconnect K and L, and weigh them; the increase in weight is the weight of $CO_2$, which, multiplied by 27.223, gives the weight of carbon.

*Volumetric Method of Estimating Phosphorus.*

The accuracy of this method will depend largely upon the correctness of the composition of the phospho-molybdate precipitate, which is adopted as a basis for calculation; this I have found after many trials to correspond with the folllowing well-known formula:

$$3(NH_4)_2O,P_2O_5,22MoO_3,12H_2O.$$

This formula contains 1.685 per cent. of phosphorus and 86.01 per cent. $MoO_3$. After reducing the $MoO_3$ to $Mo_2O_3$ by zinc and sulphuric acid, the solution is then titrated with decinormal ($\frac{n}{10}$) potassium permanganate, when the following reaction takes place:

$$5Mo_2O_3 + 6KMnO_4 + 9H_2SO_4 = 10MoO_3 + 3K_2SO_4 + 6MnSO_4 + 9H_2O.$$

From this reaction we obtain the $\frac{n}{10}$ factor of $MoO_3$ as follows: $6KMnO_4$ will form $10MoO_3$; by substituting the atomic weights for the symbols and dividing by 30, we obtain 31.568 parts of $KMnO_4$ corresponding to 47.866 of $MoO_3$; and since the $\frac{n}{10}$ factor of $KMnO_4 = 0.0031568$, that of $MoO_3 = 0.0047866$. From the

foregoing data we obtain the $\frac{n}{10}$ factor of phosphorus by this simple proportion: 86.01 : 1.685 : : 0.0047866 : x, whence x = 0.0000938, the $\frac{n}{10}$ factor of P.

*Reduction and Titration of the Phospho-Molybdate Precipitate.*— After washing the precipitate in the usual manner it must be washed twice with pure water to remove the ammonium nitrate; then dissolved in dilute ammonia, and the solution diluted to 50 or 60 c. c. Select an 8-ounce beaker, place in it a large piece of platinum foil, and on top of this about 10 grms. of granulated zinc which has been amalgamated. (The zinc amalgam is prepared by placing a quantity of granulated zinc in a dish, covering it with mercury, and adding a very dilute solution of sulphuric acid, and stirring till action ceases; now place in a funnel to drain off the excess of mercury.) Run into the beaker thus prepared 15 or 20 c. c. of the phospho-molybdate solution, and add 75 c. c. of dilute $H_2SO_4$ (1 part $H_2SO_4$ to 3 parts water); cover with a clock-glass, and apply heat till the top of the liquid is covered one-fourth of an inch deep with bubbles. Continue this heat for twenty or thirty minutes. When the reduction is complete the solution will have a brown color. Now decant the solution into a flask, and wash the residue several times with cold water; cool the solution to 60° C. and titrate immediately with $\frac{n}{10}$ $KMnO_4$, and multiply the c. c. used by the $\frac{n}{10}$ factor of phosphorus (0.0000938); the product is the amount in grams of phosphorus in the sample taken.

The solution after reduction is dark, on titration it grows lighter till it becomes perfectly white, when a few more drops of the permanganate will produce the rose-color.

My first estimations were made by using zinc and sulphuric acid to reduce the $MoO_3$; the results obtained were too high, which led me to suppose, at first, that I had employed the wrong formula for the phospho-molybdate precipitate. But I found, on making a number of tests of the same sample of steel, that my results were not uniform. This led me to look for the cause elsewhere, and I found that the error was caused by the zinc sulphate which is formed in reducing the $MoO_3$, and which reduces or destroys the permanganate. If, then, zinc is used in place of amalgamated zinc, it is necessary first to determine the reducing power of the zinc sulphate formed by dissolving a given weight, say 5 grams, of zinc; then use in the reduction a given weight of zinc, and continue the action till it is all dissolved. Now titrate the solution with $\frac{n}{10}$ permanganate, and deduct from the amount used the amount reduced by

the zinc sulphate; then multiply the remainder by the $\frac{n}{10}$ factor of P, as given above.

## Discussion.

A. E. Hunt and George H. Clapp, Pittsburgh, Pa. (communication to the Secretary):

*Manganese.*—We think Professor Cheever's wholesale condemnation of some of the standard methods for the estimation of manganese is, to say the least, too arbitrary. The acetate method and Ford's method, which Professor Cheever says give too high results, as well as the colorimetric process, which he says "never can be made to give reliable results," are extensively used by chemists of high repute, and in controlling important metallurgical operations, as well as in placing large values upon materials.

If Professor Cheever had merely said that these methods were not accurate *in his hands*, the mischief that his statement might make if allowed to go without comment would have been largely avoided.

Many of the members of the Institute who have occasion to use the results of chemical analyses, have neither the time nor the experience to keep themselves posted upon the details of chemical work; but they know in a general way that the results given them by their chemists were obtained by certain standard methods; and to see these methods arbitrarily condemned in our *Transactions* because the censurer is ignorant of or neglects the necessary precautions that pertain, in varying forms, to nearly every chemical operation, we maintain in kindness and with all due respect to Professor Cheever, is misleading, and may bring forth an unfortunate train of circumstances entirely beyond his calculations.

The objection that Professor Cheever finds to Ford's method for the estimation of manganese is that it gives too high results, owing to the lime and magnesia which the strong HCl has dissolved from the asbestos. We know of many good chemists using this method, and every one takes the necessary precautions to free the asbestos from the soluble lime and magnesia, by ignition and subsequent digestion with strong HCl and thorough washing, before attempting to use it for filtering. The venerable acetate method, which Professor Cheever says also gives too high results, and which is used, we think we are safe in saying, by a very large majority of all chemists, as the standard "check" method of analysis, can have the error due to imperfect washing of the basic acetate reduced to a very slight

amount by making a second, and, in the case of a material rich in manganese, a third separation of the iron. In practical work with steel and other materials low in manganese, the washing is often entirely done away with by making up to a known bulk the fluid in which the basic acetate separation has been made, filtering through a dry filter an aliquot part of the clear supernatant fluid, and performing the subsequent analysis for the manganese in this divided portion.

As to the statement that the colorimetric process can "never be made to give reliable results," on account of the impossibility "with peroxide of lead and nitric acid to convert all the manganese into permanganate," we have to say that we are in one of "those sections" where this method is extensively used; that we have used it since 1876, uniformly with good results; that it is necessary in this process, as in most others, to use pure reagents and to observe certain precautions in manipulation. The nitric acid must be of not over 1.20 sp. gr. in the fluid *after boiling*. It is best to start with 1.15 sp. gr. acid.

The boiling must be energetic until all the carbon is in solution and the nitrous fumes have been driven off, and the *pure* $PbO_2$ must be added to the *boiling* solution, best from a platinum spoon. The solution must then be boiled for from two and a half to three minutes, *not over* three minutes. We always time this ebullition with a watch, doing several analyses at the same time. We have checked the method upon steels very many times and with many chemists using different methods, and we find it capable of giving uniformly good results with steels of from 0.15 to one per cent. manganese.

We are in daily use of the colorimetric process, checking with our results two steel works chemists, using respectively Ford's and Volhard's methods.

*Phosphorus.*—Professor Cheever's figures for the composition of phospho-molybdate of ammonia add, we think, another to the growing list of the compositions of that interesting precipitate.

The *Metallurgical Review*, Vol. I., p. 470, gives the results of six chemists upon the phosphorus in the yellow precipitate as follows:

| | |
|---|---|
| Sonnenschein, | 1.27 per cent P. |
| Eggertz, | 1.63 " " |
| Seligsohn, | 1.33 " " |
| Lipowitz, | 1.57 " " |
| Struve and Sramberg, | 1.58 " " |
| Nutzinger, | 1.67 " " |

And our *Transactions* quote results from 1.54 per cent. to 1.75 per cent. phosphorus. We think the majority of chemists use

Eggertz's original figure of 1.63 per cent. phosphorus in the phospho-molybdate of ammonia when thoroughly dried at 60° C.

PROF. CHEEVER (communication to the Secretary): The remarks of Messrs. Hunt and Clapp upon my paper neither discuss nor criticise the processes I recommend. Their main efforts are directed to what they call my "wholesale condemnation" of other processes.

A candid examination of the paper will show a very simple statement, and one not fraught with so much danger to those processes, except perhaps the colorimetric, as these gentlemen seem to think. When they charge in substance that I am ignorant of or neglect "the necessary precautions," they use rather strong language, especially since there are many chemists in this country and foreign countries, who have made the same statements as my paper contains. I have much and good company.

In working by Ford's method, which is among the best, I found lime in some of my manganese phosphate precipitates; and in seeking for the cause, I found that my *purified* asbestos gave up soluble matter on again being treated with strong HCl. I corresponded with other chemists upon the subject, and found that they had met with the same difficulty.

As to the acetate method, there has been so much written upon the defects of the process, that any further comment is unnecessary. Messrs. Hunt and Clapp touch only one of its important defects.

The colorimetric process has been worked up by a German chemist, and his conclusions can be found in *Annalen der Chemie*, vol. cxcviii., p. 362. They are far from complimentary to the process. Some work has been done on the process here, which led to the conclusions expressed in my paper.

The composition of the phospho-molybdate of ammonia is to be found in so many authorities that I will not refer to them. From the formula given, any one can calculate the percentage of phosphorus, which is that in the moist precipitate; the per cent. given by the authors referred to, is of the dry precipitate, no formula being given.

## *MR. E. D. CAMPBELL'S COLORIMETRIC PROCESS FOR ESTIMATING PHOSPHORUS IN IRON AND STEEL.*

BY BYRON W. CHEEVER, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN.

THE greatest objection to be brought against the present methods for estimating phosphorus in iron and steel, is the time consumed in the operation. The following method, originated and perfected by Mr. E. D. Campbell, assistant in the chemical laboratory of the University of Michigan, will, I think, if carefully followed out, give results that are sufficiently accurate for technical purposes, and will give them in less time than they can be obtained by any other process.

The process consists in comparing the color obtained by the action of stannous chloride upon a solution of the phospho-molybdate precipitate obtained from the solution of iron or steel, with that obtained from a standard solution of molybdic acid which represents a given amount of phosphorus. The operation is as follows:

Take of ordinary steel 1 grm. and treat as in any of the well-known processes until the phosphorus is precipitated as ammonium-phospho-molybdate. When precipitated, the phospho-molybdate precipitate is filtered out, thoroughly washed with an acid solution of ammonium nitrate, and, finally, twice with water, to remove most of the ammonium nitrate. The precipitate is then dissolved in about 1 c. c. of 10 per cent. potassium hydrate, which is let fall drop by drop on the filter till the precipitate is dissolved; the filter is now washed with about 25 or 30 c. c. of water, and the potassium hydrate solution, which now consists of 25–32 c. c. of solution, is boiled until the peculiar frothy appearance, which first appears on boiling, is entirely gone. The solution is then cooled until perfectly *cold*, and about 10 or 15 c. c. of strong hydrochloric acid added; if the solution is kept cold this will form no precipitate, but a light yellow or colorless solution. The solution is now ready for the addition of stannous chloride, and the subsequent comparison of color produced with that obtained from the standard molybdic acid. The comparison is made in tubes that are calibrated like carbon-tubes, but which are larger, about $\frac{5}{8}$-inch bore, and graduated to 100 c. c.; this makes them about 18 inches long.

To make the comparison of color, first transfer the now acid solu-

tion of the phospho-molybdate precipitate to one tube, then in the other place 5 c. c. of a solution of molybdic acid, 1 c. c. of which is equivalent to .0001 grm. phosphorus. The standard is then diluted with stannous chloride to 20 c. c.; this gives a brown solution, 1 c. c. of which is equivalent to .000025 grm. of phosphorus. About 15 or 20 c. c. of stannous chloride is then added to the tube containing the solution of the unknown, and the solution kept cold by a stream of cold water till the bubbles cease rising to the top; there will almost always be an evolution of nitric oxide due to the ammonium nitrate, which remains unremoved when washing, and the nitric acid of which acts on the reduced molybdenum and stannous chloride; this must be destroyed before a permanent color is produced. When the evolution of nitric oxide has ceased and a permanent color has been produced, the color is compared with that of the standard; if the unknown is lighter than the standard, the latter is diluted with stannous chloride to 40 c. c., when each c. c. becomes equivalent to .0000125 grm. of phosphorus. The tubes are now placed in a carbon-box and the unknown diluted with stannous chloride until the intensity of color is the same in both solutions. From the number of c. c. the amount of phosphorus can be easily calculated, and from this the per cent. of phosphorus in the sample.

The two important solutions are the stannous chloride and the standard molybdic acid.

*Stannous Chloride Solution.*

| | |
|---|---|
| $SnCl_2$, | 200 grms. |
| HCl, 1.16 specific gravity, | 325 c. c. |
| $H_2O$, | 600 c. c. |

The HCl is added to the $SnCl_2$ and then the $H_2O$ and the whole heated on a water-bath until the solution is perfectly clear.

*Standard Molybdic Acid Solution.*

Take 5 grms. of molybdenum trioxide, dried at 100° C., add 200 c. c. of strong hydrochloric acid, and boil until a clear solution is obtained; this is then cooled and diluted with water to about 900 c. c., and is then to be standardized. To standardize this, take about 5 grms. of steel in which the phosphorus has been accurately determined, and precipitate and treat the phospho-molybdate as before directed up to the acidification with hydrochloric acid. After the solution has been acidified with hydrochloric acid, it is

diluted to such a point that each c. c. shall contain .0001 grm of phosphorus. This will give a temporary standard solution, but it will precipitate in a day or two; to avoid which evil, we standardize a solution of molybdic acid in hydrochloric acid, as this will keep indefinitely without changing. If we had 5 grms. of steel with 0.15 per cent. phosphorus, there would be .0075 grms. of phosphorus, and the solution would have to be diluted to 75 c. c. in order that each c. c. should be equal to .0001 grm. of phosphorus. To compare the two solutions, take 5 c. c. of the temporary standard, add 20 c. c. of stannous chloride, and, when the effervescence has ceased, more stannous chloride, until the whole is diluted to 40 c. c. in the color-tube. Each c. c. of this solution is then equivalent to .0000125 grm. of phosphorus, which gives a very good depth of color for comparison. 5 c. c. of the hydrochloric acid solution of the molybdenum trioxide is then placed in the other tube and diluted with stannous chloride till the colors of the two solutions agree.

Let $a$ be the amount to which the 5 c. c. of molybdic acid solution had to be diluted in order to equal the standard in color, and $b$ be the amount of solution in the cylinder, or whatever it is to be diluted in. Then,

$40 : a :: b : x$, in which $x$ is the amount to which $b$ will have to be diluted in order that each c. c. shall be equivalent to .0001 grm. of phosphorus. In this way a permanent standard solution of molybdic acid can be made which can be diluted a little at a time, when desired, with stannous chloride, to give a standard color.

I have found that where the carbon in a sample of steel has been destroyed by means of potassium chlorate, and the manganese precipitated as the dioxide, if, instead of hydrochloric acid, ammonium oxalate be used to reduce the manganese, and the solution then boiled nearly to dryness, or until almost all the nitric acid has been driven off, the iron precipitated with ammonium hydrate and redissolved in nitric acid and boiled a few minutes, a clear straw-colored solution is obtained from which the phosphorus may be completely precipitated by ammonium molybdate in forty minutes if the solution is heated to 60° C. The precipitation takes place almost immediately, and seems to be nearly complete in ten minutes, although I generally allow forty minutes.

By adopting the two above methods, I have made estimations of phosphorus in steel agreeing to within less than .01 per cent. with those obtained gravimetrically, and have completed the estimations

in a little more than three hours from the time I began to weigh. One estimation I completed in two hours and fifty minutes, and I think, with practice, the time could be reduced to two hours and thirty minutes.

---

## *A NEW METHOD FOR THE DETERMINATION OF PHOSPHORUS IN IRON AND STEEL.*

BY J. B. MACKINTOSH, SCHOOL OF MINES, NEW YORK.

THE general method which has been followed since the time of Heinrich Rose, and perhaps before, for the determination of phosphorus in iron and steel, is to dissolve the sample either in nitric acid, *aqua regia*, or some other oxidizing agent, in order to convert the phosphorus into phosphoric acid.

In 1832 Rose* recommends $HNO_3$, or *aqua regia*, preferably the former. Wöhler, in 1854,† directs that the iron should be oxidized by burning in a stream of oxygen for the determination of carbon, and the resulting oxide of iron containing all the phosphorus as phosphoric acid be treated as an ore. In the fourth English edition of Fresenius' *Quantitative Analysis*,‡ pp. 666–667, we find directions to dissolve the iron in *aqua regia* or bromine; and, coming down to more recent times, we find F. A. Cairns§ directing the employment of a boiling solution of potassium chlorate and hydrochloric acid for the oxidation and solution of the sample to be analyzed. It is unnecessary to multiply quotations from the literature of the subject, though they might be extended almost indefinitely, since it would only be a repetition of the above mentioned series of methods in one form or another; and the references given have been selected to show how little essential variation there is in the type-methods of solution used. In fact it seems to be universally accepted as a necessary first step in the determination that some such method of solution should be followed.

One chemist, however, struck out on a different line of thought, and to the best of my knowledge only one, M. V. Tantin, who, in

* Rose's *Traité Pratique d'Analyse Chimique.* Translated from the second German edition, by A. J. L. Jourdan, 1832, vol. ii., p. 414.

† Wöhler's *Handbook of Inorganic Analysis.* Edited by A. W. Hofmann. London, 1854, p. 61.

‡ 1865.

§ *A Manual of Quantitative Chemical Analysis.* By F. A. Cairns, A.M., 1880, p. 114.

a contribution to the *Comptes Rendus* (I have not been able to find the original article, however), copied in the *Chemical News*,* describes his method for determining phosphorus in cast-iron as follows:

"When seeking the means of avoiding these sources of error,† I concluded that the best way of so doing would be to use a precisely contrary method, namely, by liberating the phosphorus as a hydrogen compound; but one objection naturally arose—would the totality of the phosphorus pass into the state of a gaseous product? I may safely affirm that I have never been able to discover the least trace of phosphorus in the residue after the complete attack of the cast-iron by chlorhydric acid, which fact is not surprising if it be considered what strong affinities phosphorus has for hydrogen."

According to M. Tantin, the resulting gases, composed of phosphuretted, arsenuretted, sulphuretted, and carburetted hydrogen, are passed through potash and then into nitrate of silver, where all the phosphuretted hydrogen is caught as phosphide of silver, which is afterwards treated with *aqua regia*, and the phosphoric acid resulting determined as ammonic-magnesic phosphate. The following precautions are mentioned as indispensable.

1. The cast-iron must be attacked very slowly, or part of the phosphuretted hydrogen may traverse the solution of nitrate of silver without being absorbed.

2. When the solution is finished, a current of hydrogen is to be passed through the apparatus.

M. Tantin seems to have overlooked the possibility of some of the phosphorus remaining in the solution, and to have assumed that if none was found in the residue, all must have gone off with the gas. If such were the case, the determination of phosphorus would be much simplified.

Some years ago, I tried this method on a pig-iron which I knew ran over one per cent. of phosphorus, but my final precipitate, if any, of ammonic-magnesic phosphate, was so small as to be invisible. I concluded that the method was not suited for American pig-irons, and gave no more attention to the subject till the present summer, during which I have had considerable leisure time for experiment.

In Watt's *Dictionary of Chemistry*‡ we find the statement, "When a very small quantity of phosphorus is associated with a large quan-

* *Chemical News*, xviii., p. 252.

† Loss as phosphuretted hydrogen; estimation of arsenic as phosphorus; and errors due to large bulk of solutions employed.

‡ 1866. Vol. iv., p. 519.

tity of iron, as in many kinds of pig-iron, the whole dissolves in hydrochloric or dilute sulphuric acid, the phosphorus passing into solution as phosphoric acid." This statement is the very reverse of that made by M. Tantin, and to ascertain its accuracy I made the following experiment.

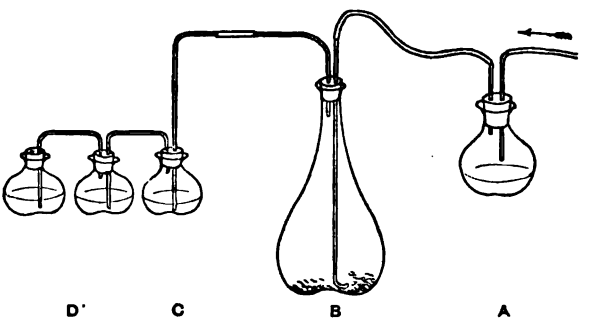
I had just finished an analysis of bar-iron which, by the ordinary method I used,* had given 0.124 per cent. phosphorus. I took 10 grams of this and dissolved it in hydrochloric acid, finally boiling the solution, neutralized with ammonia, and, after adding a few c.c. of permanganate to oxidize a little iron, precipitated basic acetates, boiling the filtrate twice for further precipitates; the combined precipitates were dissolved in hydrochloric acid, oxidized with nitric, precipitated with ammonia and the precipitate redissolved in nitric acid, and the phosphorus precipitated with ammonium-molybdate, finally weighing the yellow precipitate. The result I obtained by this method was 0.122 per cent., which is a very satisfactory confirmation of the statement the experiment was meant to verify. The time taken in this determination was about from 5 to 6.30 P.M. one evening, by which time I had the yellow precipitate formed,† and the time necessary to filter and weigh the precipitate the next day, perhaps an hour more.

This result being so satisfactory, I treated some filings of a high-phosphorus pig (in which by my ordinary method I had found 0.826 per cent.) in the same manner, but found that I had only succeeded in obtaining 0.580 per cent., or about five-sevenths of the total amount present. I also prepared a button of very high-phosphorus iron, and on treating in the same way found that I only obtained about three-quarters of the amount present. This made me think that probably the loss was due either to the escape of phosphuretted hydrogen or to the formation of some other compound than phosphoric acid. I therefore arranged a simple apparatus, the

* Ten grams dissolved in 120 c.c. nitric acid sp. gr. 1.20, evaporated to dryness and heated in air-bath to 120° to 130° C. several hours, redissolved in hydrochloric acid, reduced with ammonium bisulphite: precipitate the phosphoric acid by a basic acetate separation, boil the filtrate twice for further precipitates, making three in all, dissolve the combined precipitates in hydrochloric acid, filter out silica, oxidize solution with nitric acid, precipitate with ammonia, redissolve the precipitate in nitric acid and precipitate with ammonic molybdate. This last precipitate is redissolved in ammonia and reprecipitated by nitric acid, is then filtered on a Gooch crucible, dried and weighed, and afterwards checked by precipitation as ammonic-magnesic phosphate.

† I did not seek to remove silica by evaporation to dryness. Per cent. Si = 0 151.

same, in fact, which I use for the determination of sulphur in iron, which is filled with an atmosphere of hydrogen throughout the operation, and consists of a flask A to hold the acid, a flask B for the iron, and flasks C and D, of which C is generally left empty to catch condensed steam, and the two flasks D contain the absorbent liquid.




The absorbent liquid in D was a solution of potassium-permanganate acidified with nitric acid. The iron having been placed in B, and the necessary amount of dilute hydrochloric acid to dissolve it in A, the whole apparatus was filled with hydrogen, a current of which was kept passing through the whole time. When the air was all expelled, the flask A was inverted above the level of B, so that its contents flowed into B and the solution of the iron commenced. The solution was heated to boiling for some minutes, and when all had dissolved, with the exception of the insoluble portion, the apparatus was disconnected, the insoluble residue filtered from the solution, the solution divided into equal parts, one of which was oxidized with nitric acid and treated as in an ordinary determination of phosphorus, while the other was immediately precipitated by basic acetate, as in the first experiment described.* The amounts of phosphorus found in the prepared iron phosphide were distributed as below.

| | | | |
|---|---|---|---|
| In residue, . . . . . | 3.79 per cent. | | |
| In solution { oxidized with nitric acid, | 2.66 " | | |
| In solution { basic acetate direct, . | | | 2.16 per cent. |
| In gas, . . . . . | 0.05 " | | |
| | 6.50 " | | |

Showing a loss of 0.50 per cent. of phosphorus in the solution in some other form than phosphoric acid. It is very possible that nitric acid fails to oxidize to phosphoric acid all the phosphorus

* Care being taken to remove silica wherever present.

compounds formed in the solution. Referred to the total amount of phosphorus found (6.50 per cent.), the distribution per cent. is as follows:

| | |
|---|---|
| In residue, | 58.31 |
| Recovered from basic acetate precipitation, | 33.23 |
| Lost, | 7.69 |
| In gas, | 0.77 |
| | 100.00 |

I repeated the above process on a sample of pig-iron said to contain 0.885 per cent. phosphorus, and in which, by my usual method, I found 0.880 per cent. weighing as magnesia pyro-phosphate, or, calculating from the weight of the yellow precipitate, 0.878 per cent. This was also conducted in a hydrogen atmosphere. The gas was caught in permanganate acidified with sulphuric acid in the first flask and with nitric acid in the second. Nearly all the phosphorus in the gas was retained in the first flask, a very small amount only passing over to the second. The results obtained were—

| | | |
|---|---|---|
| Phosphorus in residue, | 0.345 | per cent. |
| In solution { basic acetate precipitate, | 0.451 | " |
| In solution { lost, | 0.065 | " |
| In gas, | 0.019 | " |
| | 0.880 | " |

The distribution of the phosphorus is—

| | | |
|---|---|---|
| In residue, | 39.11 | per cent. |
| In solution { basic acetate precipitate, | 51.13 | " |
| In solution { loss, | 7.60 | " |
| In gas, | 2.16 | " |
| | 100.00 | |

I then took a sample of high-phosphorus pig in which I had found in usual way 1.45 per cent. (weighed as yellow precipitate), or 1.48 per cent (weighed as magnesia pyrophosphate), and dissolved 1 gram in 10 c.c. hydrochloric acid, and 30 c.c. water, finally heating the solution to boiling. This time, instead of a stream of hydrogen being passed through the apparatus, a stream of oxygen was employed. The escaping gas was passed through permanganate and nitric acid. All the phosphorus caught was found in the first flask.

The residue, as in all these experiments, was heated with nitric acid and potassium chlorate; the solution was partially oxidized with 10 c.c. permanganate (1 c.c. = .01 Fe) and precipitated as basic acetate as usual; the silica separated from both portions, and the

phosphorus determined. The total amount of phosphorus found was 1.42 per cent. weighed as magnesia pyrophosphate, or 1.37 per cent., weighed as the yellow precipitate, showing a loss of 0.06 per cent. The distribution of the phosphorus was:

| | | | |
|---|---|---|---|
| In residue, | | 37.47 | per cent. |
| In solution | basic acetate precipitate, | 55.20 | " |
| | loss, | 4.05 | " |
| In gas, | | 3.28 | " |
| | | 100.00 | |

I next took 2 grams of the .880–.885 per cent. pig and dissolved it, as in the last case, in a stream of oxygen, but instead of following up each portion separately, mixed them all together (the gas was caught in sulphuric acid permanganate), and collected the residue with the first basic acetate precipitate, treated with nitric acid and potassium chlorate, and proceeded as before. The phosphorus found was only 0.771 per cent., or of the total amount present, 87.41 per cent. was found and 12.59 per cent. lost.

I repeated the last experiment, using, however, dilute sulphuric acid in place of hydrochloric as the solvent, a stream of oxygen passing continually through, and the solution being kept boiling for fifteen minutes, after all visible action had ceased. The total phosphorus found was 0.767 per cent., distributed as follows:

| | | |
|---|---|---|
| In residue, | | 14.17 |
| In solution, | basic acetate precipitate, | 70.86 |
| | loss, | 13.16 |
| In gas, | | 1.81 |
| | | 100.00 |

These last two experiments showed that oxygen was not sufficient to convert the phosphorus in the forms lost into phosphoric acid; so the problem resolved itself into finding a method of converting the lower oxygen compounds of phosphorus into phosphoric acid, without simultaneously oxidizing ferrous to ferric iron. The solution of this problem was obtained in the next trial. The process is the same as before described, using hydrochloric acid as the solvent, and a current of oxygen ;* and after raising the solution to boiling, introducing an excess of a strong solution of sulphurous acid previously

* The use of oxygen in place of hydrogen is recommended because it has no appreciable oxidizing effect on the iron solution, while it prevents the reduction of the permanganate, which rapidly takes place with hydrogen.

| Number. | Sample. | Per ct. P. | Method employed. | Per ct. P. found. | | | Total per ct. found. | Loss. | Per cent. distribution. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Residue. | Solution. | Gas. | | | Residue. | Solution. | Gas. | Loss. |
| 1 | Bar-iron, . . . | 0.124 | Sol. in HCl and direct basic acetate precipitation. | 0.122 | | ..... | 0.122 | 0.002 | ..... | 98.4 | ..... | 1.6 |
| 2 | Pig, . . . . . | 0.826 | Sol. in HCl and direct basic acetate precipitation. | 0.580 | | ..... | 0.580 | 2.46 | ..... | ..... | ..... | ..... |
| 3 | Iron phosphide, | 6.50? | Sol. in HCl in H atmosphere. Gas absorbed in $K_2Mn_2O_8$ and $HNO_3$. | 3.79 | 2.16 | 0.05 | 6.00 | 0.50 | 58.31 | 33.23 | 0.77 | 7.69 |
| 4 | Pig, . . . . . | 0.880 | Sol. in HCl in H atmosphere. Gas in $K_2Mn_2O_8 + H_2SO_4$. | 0.345 | 0.451 | 0.019 | 0.815 | 0.065 | 39.11 | 51.13 | 2.16 | 7.60 |
| 5 | Pig, . . . . . | 1.48 | Sol. in HCl in O atmosphere. Gas in $K_2Mn_2O_8 + HNO_3$. | ..... | ..... | ..... | 1.42 | 0.06 | 37.47 | 55.20 | 3.28 | 4.05 |
| 6 | Pig, . . . . . | 0.880 | Sol. in HCl in O atmosphere. Mixed all portions. Gas in $K_2Mn_2O_8 + H_2SO_4$. | ..... | ..... | ..... | 0.771 | 0.109 | ..... | 87.41 | ..... | 12.59 |
| 7 | Pig, . . . . . | 0.880 | $H_2SO_4$ in O atmosphere and solution boiled 15 minutes. | ..... | ..... | ..... | 0.767 | 0.111 | 14.17 | 70.86 | 1.81 | 13.16 |
| 8 | Pig, . . . . . | 0.880 | HCl in O atmosphere boiled with excess $SO_2$. | ..... | ..... | ..... | 0.882 | *gain.* 0.002 | 13.49 | 80.84 | 5.67 | 0.00 |
| 9 | Pig, . . . . . | 0.880 | HCl in O atmosphere, boiled with excess $SO_2$, but all portions mixed. | ..... | ..... | ..... | 0.865 | 0.015 | Slight loss in course of analysis. | | | |

placed in the flask A, and continuing the boiling for some minutes. The result of the reaction is visible in the precipitation of sulphur in the solution, and the insoluble residue is much altered in appearance, being much more disintegrated. The results obtained in this experiment were: total phosphorus present, 0.882 per cent., weighed as magnesia pyrophosphate (care being taken to ensure its purity by resolution and reprecipitation of the magnesia precipitate), distributed

| | |
|---|---|
| In residue, | 13.49 per cent. |
| In solution, | 80.84 " |
| In gas, | 5.67 " |
| | 100.00 " |
| Loss, | 0.00 " |

In confirmation of this result, I made another determination in the same manner, starting at noon; by the following morning I found 0.865 per cent. of phosphorus, and had lost a small amount in the course of the rather hurried analysis.

The results obtained are given in tabular form on the preceding page.

I also made some confirmatory experiments on the sample used in experiment No. 5, weighing the yellow precipitate first obtained, instead of purifying it by reprecipitation. The precipitates carried traces of iron, which in experiments 11 and 12 entered into the magnesia precipitates. This explains discrepancies observable between the results calculated from the weights of the yellow precipitate and from those of the magnesic pyrophosphate.

| Percentage P. | Old Method. | New Method. | | |
|---|---|---|---|---|
| | No. 5. | No. 10. | No. 11. | No. 12. |
| Weighed as yellow precipitate, . . . | 1.447 | 1.49 | 1.451 | 1.463 |
| No. of precipitations, . | 2 | 1 | 1 | 1 |
| Weighed as $Mg_2P_2O_7$, . | 1.480 | 1.456 | 1.516 | 1.539 |
| No. of precipitations, . | 1 | 2 | 2 | 1 |

From inspection of this table it is seen that there is a far closer agreement between the results calculated from the weights of the yellow precipitate than in those calculated from the magnesic pyrophosphate; and I am of the opinion that the true percentage of this sample is very near 1.454, the average of the four lowest results obtained.

In experiment 10, the phosphorus found was distributed—

| | |
|---|---|
| In residue, | 23.10 |
| In solution, | 73.00 |
| In gas, | 3.90 |
| | 100.00 |

In experiments 11 and 12, all portions were mixed together.

The following is a brief outline of the steps to be followed:

1. Solution in hydrochloric acid in a stream of oxygen or air, absorbing the escaping gases in permanganate acidified with sulphuric acid.

2. Heating the solution to boiling, stopping the passage of the oxygen current, and carefully adding an excess of sulphurous acid solution, and continuing the boiling till the precipitated $MnO_2$ in the absorption-flasks is redissolved. This boiling should last several minutes to ensure the completion of the reaction.

3. Disconnecting the junctions between the absorption-flasks and solution-flask, and between the solution-flask and the acid-flask, and allowing to cool.

4. Mixing solutions, filtering out residue which is placed (with filter paper) in a porcelain casserole, oxidizing with nitric acid and potassium chlorate, and evaporating to dryness.*

5. Boiling the solution till the excess of sulphurous acid is expelled, adding a few c.c. of permanganate to peroxidize a little of the iron, and precipitating basic acetates. Boiling the filtrate for other precipitates, to ensure getting all the phosphoric acid present.

6. Dissolving these precipitates in hydrochloric acid and adding to the solution of the residue in which, by this time, the paper will have been thoroughly destroyed.

* I prefer to filter out the residue instead of filtering it out with the first basic acetate precipitate, because it is difficult to work accurately on a muddy liquid, and because there is a probability of loss of phosphorus by the continued action of the hot acid solution on the residue, after the sulphurous acid has been expelled. By proceeding as directed, this chance of loss is removed. Perhaps some of the loss in the ninth experiment may be due to this cause, as the residue in that experiment was not separately treated.

7. Evaporating to dryness for silica, and proceeding as usual with the molybdate precipitation.

The saving of time by this process is the greater, as the percentage to be determined is less. In a steel of low percentage, where it is necessary to use 10 grams for the determination, necessitating the use of 120 c.c. of nitric acid for solution, by the old method, the time taken for the evaporation of this amount of liquid, for the subsequent thorough drying of the residue, and for the resolution and reduction of the iron to the ferrous state, is evidently much greater, and the operations followed are much more tedious than by this method, where the phosphorus is concentrated at the start in but a few milligrams of iron in very little bulk of solution, enabling the subsequent evaporation to dryness and thorough drying of the residue to be performed in a very short period.

In M. Tantin's experiments he used cast-iron only. Mine have been conducted on pig and wrought-iron. It is possible that the difference in our results may be partially accounted for by different modes of occurrence of phosphorus similar to the different forms of carbon, but of this I cannot speak from experience, and merely offer it as a suggestion.

The small amount of phosphuretted hydrogen which is found, seems to be the product of a secondary reaction between phosphorous acid and the nascent hydrogen evolved. Whether hypophosphorous or hypophosphoric acids are present, or, indeed, whether phosphorous acid is present, I am at present unable to say, but the results obtained point to the presence in the solution, along with phosphoric acid, of one or more of these, as the cause of loss. The use of sulphurous acid, however, oxidizes these to phosphoric acid without affecting the iron, so that by this process, a determination can be made in a day which formerly required several days.

In calculating the percentage of phosphorus from the weight of the yellow precipitate, I have used in all cases the figure of 1.63 per cent. phosphorus in the precipitate, and have thought it worth while to give the results I have obtained in two determinations I have recently finished. I prepared the yellow precipitate from phosphoric acid, precipitated in the usual manner with excess of molybdic acid. One of these precipitates (A) was purified from possible excess of molybdic acid by solution and reprecipitation; the other (B) was analyzed without going through this process. The magnesia precipitate obtained from A was also purified by solu-

tion and reprecipitation, while that from B was ignited and weighed direct. The results are given below.

| | A | B |
|---|---|---|
| Weight of yellow precipitate dried at 95°–100° C., . . | 1.2802 | 1.1428 |
| Weight of $Mg_2P_2O_7$, . . . . . | .0735 | .0664 |
| Weight of P. calculated from $Mg_2P_2O_7$, . . . . . | .02053 | .01854 |
| Percentage of P. in yellow precipitate, . . . . . | 1.603 | 1.623 |
| Weight of P. calculated from yellow precipitate, assuming factor 1.63 per cent., . . . . . | .02087 | .01863 |

## *LIXIVIATION AND AMALGAMATION TESTS.*

BY F. W. CLARK, BOSTON, MASS.

AT the present time, when lixiviation *versus* amalgamation is being so thoroughly discussed by practical men, and published information is so meagre, the following tests, made by students in the mining laboratory of the Massachusetts Institute of Technology, may be of interest to others. The ore experimented upon was obtained from the Sombrerete mines near Zacatecas, Mexico. A careful analysis of the dried sample resulted as follows:

| | Per cent. |
|---|---|
| $SiO_2$, . . . . . | 62.79 |
| S, . . . . . | 13.86 |
| $Al_2O_3$, . . . . . | 4.39 |
| Fe, . . . . . | 11.26 |
| Zn, . . . . . | 1.57 |
| CaO, . . . . . | 2.91 |
| MgO, . . . . . | 0.06 |
| Cu, . . . . . | 0.12 |
| Pb, . . . . . | 0.40 |
| Sb and As, . . . . . | trace |
| $CO_2$, . . . . . | 2.35 |
| Ag, . . . . . | 0.16 |
| | 99.87 |

| Mineral. | Per cent. |
|---|---|
| Quartz, | 58.79 |
| Slate, | 8.21 |
| Calcite, | 5.26 |
| Siderite, | trace |
| Sphalerite, | 2.34 |
| Galena, | 0.46 |
| Pyrite, | 24.12 |
| $Cu_2S$, | 0.14 |
| Ruby silver, | 0.26 |
| | 99.58 |

Two lots of the ore were taken for treatment: the first, weighing 446 k. (981 pounds), was treated by the Patera and Russell processes, by Mr. O. T. Stantial; and the second, weighing 201 kilos. (442 pounds), was treated by the ordinary roasting and amalgamation process, by Mr. N. M. Randall.

*Lixiviation Tests.*—The ore was crushed with rolls to pass a 30-mesh sieve. Several trial-charges of 10 kilos. (22 pounds) each were roasted in a small reverberatory furnace (hearth 2 feet x 2 feet) under varying conditions, such as mixing salt with ore before charging, mixing salt at different periods of the roast, varying heat and length of roast, etc. Each charge was carefully sampled, the sample finely ground and assayed to ascertain the percentage of silver chloridized; and the results were invariably higher than those afterwards obtained in leaching the charge. It is probable that some of the ore-particles, partially fused in the roasting, were impervious to the solutions. The charges were leached first with water, then with a solution containing about 4 per cent. of hyposulphite of soda until no precipitate was given on addition of $Na_2S$, and finally with a Russell solution containing about 4 per cent. $Na_2S_2O_3$ and 2 per cent. bluestone.

Table I. gives the results of trial charges.

TABLE I.

| No. | Weight. | Roasted without salt. | Roasted with salt. | Per cent. salt used. | Per cent. AgCl by assay. | Per cent. silver obtained by leaching. | | Total extracted. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | With hyposulphite. | With Russell solution. | |
| | K. | Hours. | Hours. | | | | | |
| 1 | 10 | 0 | 2 | 10 | 73.34 | 66.40 | 16.74 | 83.14 |
| 2 | 10 | 2 | 2 | 10 | 90.00 | 85.71 | 4.56 | 90.27 |
| 3 | 10 | 1 | ½ | 5 | 85.30 | 80.78 | 8.76 | 89.54 |
| 4 | 10 | 1½ | 3 | 10 | 87.90 | 81.32 | 9.55 | 90.87 |
| 5 | 10 | 2¼ | 3 | 10 | 85.50 | 84.47 | 5.60 | 90.07 |
| 6 | 20 | 1 | 2 | 10 | 75.98 | 48.23 | 34.04 | 82.27 |

These trial-charges being satisfactory, the main part of the ore was roasted in four charges in a reverberatory furnace (hearth 4 feet by 4 feet). Ten per cent. of salt was used with each charge, though half that quantity would probably have given nearly as good results. The salt was added towards the end of the roast in each case. The loss of silver by volatilization was determined by estimating total amount of silver present before and after roasting. This includes loss in flue-dust and loss due to the furnace not being thoroughly cleaned out. It is probably too high in the first two roasts and too low in the latter two.

In leaching, cold water was admitted below the charge and diluted as it rose above, considerable chloride of silver being precipitated. Cold, and finally warm, water was passed through, until the addition of $Na_2S$ gave no precipitate. A 3.3 per cent. solution of hyposulphite slightly warmed was then passed through the ore until the addition of $Na_2S$ to the filtrate produced no precipitate, but only a deep wine-color. Finally, a Russell solution containing 3 kilos. hyposulphite and 1½ kilos. bluestone to 40 gallons of water was used, until no more silver would dissolve. The results of each charge are given in Table II.

TABLE II.

| No. | Weight. | Roasted without salt. | Roasted with salt. | Weight of ore after roast. | Silver assay before roast. | Silver assay after roast. | Per cent. Ag lost in roasting. | Per cent. soluble salts. | Per cent. AgCl by assay. | Per cent. AgCl leached by $H_2O$. | Per cent. AgCl leached by hyposulphite. | Per cent. AgCl leached by Russell solution. | Total per cent. Ag extracted. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K. | Hours. | Hours. | K. | Oz. per ton. | Oz. per ton. | | | | | | | |
| 1 | 80 | 3 | 2 | 78.6 | 46.93 | 38.1 | 20.25 | 13 1 | 92.4 | 12.6 | 63.87 | 7.27 | 83.74 |
| 2 | 80 | 3 | 1 | 75.1 | " | 41.36 | 17.5 | 13.2 | 70.2 | 12.2 | 55.58 | 17.96 | 85.74 |
| 3 | 80 | 3 | 1 | 80 | " | 45.86 | 2.29 | 15 2 | 87.8 | 10.3 | 52.94 | 19.01 | 82.25 |
| 4 | 59.4 | 2 | 1 | 59. | " | 46.33 | 2.09 | 14.8 | 84.6 | 13.8 | 54.98 | 9.16 | 77.94 |

Charge two roasted at low heat. Charge four at a heat that baked it badly.

It is probable that a lower heat than that used would have given better results, but time and ore were insufficient to continue experiments.

*Amalgamation Tests.*—Ore crushed to pass a 30 mesh sieve. Four trial-charges roasted in small furnace, and two larger lots in large furnace, gave the results shown in Table III. All charges were well mixed and amalgamated in 12-inch and 18-inch combination pans. Table IV. shows the results of amalgamation.

TABLE III.

| No. | Weight of ore. | Roast without salt. | Roast with salt. | Per cent. salt. | Assay before roast. | Assay after roast. | Per cent. Ag volatilized. | Per cent. AgCl. | Per cent. soluble salts. |
|---|---|---|---|---|---|---|---|---|---|
| | K. | Hours. | Hours. | | Oz. per ton. | Oz. per ton. | | | |
| 1 | 11 | 1½ | ½ | 10 | 56.1 | 54.8 | 3.63 | 88.7 | ... |
| 2 | 10 | 1½ | ¾ | 7 | " | 53.5 | 12.5 | 86.5 | ... |
| 3 | 10 | 1¼ | 1 | 10 | " | 54.2 | 8.0 | 85.5 | ... |
| 4 | 11 | 0 | 2 | 5 | " | 52.9 | 6 2 | 77.3 | ... |
| 5 | 80 | 4½ | 1½ | 10 | 49.6 | 46.4 | 7.21 | 87.8 | 15.11 |
| 6 | 80 | 5 | 2 | 10 | 49.6 | 44.6 | 9.65 | 88.9 | 14.9 |

TABLE IV.

| No. | Weight. | Ground. | Amalgamated. | Total time. | Temperature. | Per cent. Ag extracted. | Fineness of bullion. |
|---|---|---|---|---|---|---|---|
| | K. | Hours. | Hours. | Hours. | C. | | |
| 1 | 25 | 2 | 2 | 4 | ... | 62.6 | 395 |
| 2 | 25 | 0 | 2 | 2 | ... | 80.4 | 625 |
| 3 | 19 | 1 | 2 | 3 | 74° | 66.7 | 131 |
| 4 | 9 | 1 | 2 | 3 | 80° | 47.5 | 597 |
| 5 | 16 | ½ | 3½ | 4 | 74° | 83.1 | 132 |
| 6 | 16 | 2¾ | 2¾ | 2¾ | 67° | 79.5 | 292 |
| 7 | 16 | 3¼ | 3¼ | 3¼ | 55° | 84.7 | 241 |
| 8 | 16 | 1 | 4 | 5 | 70° | 74.4 | 128 |
| 9 | 16 | 1 | 4 | 5 | Cold. | 82.6 | 95 |
| | Tailings re-treated gave..... | | | | | 84.61 | 190 |

These tests show that this ore can be worked equally well by either process. The leaching gives nearly pure bullion. That from amalgamation can be improved very much by further studying the conditions of amalgamation and roasting. The weakest point of the Russell process is in handling the mixed sulphides of copper and silver. It is not claimed that the results by either process are as good as would be obtained by continuous working of the ore; but they are interesting as showing what comparatively inexperienced workers can do at the first attempt with a rather difficult ore.

The gases given off during the chloridizing period were examined qualitatively by drawing them off from the interior of the ore-pits and leading them through suitable condensing apparatus and different solutions. These gases were Cl, HCl, $SO_2$, $SO_3$, and the ordinary products of combustion. The chlorides of Fe, Ag (a trace), Pb, Na, Zn (a trace), Ca (a trace), Cu, As, and Sb (a trace) were also given off.

Another student, Mr. David Baker, made a large number of tests with a highly oxidized manganese ore from the Knoxville mine, Charleston, Arizona.

The ore analyzed as follows:

| | |
|---|---|
| $MnO_2$, | 54 83 |
| MnO, | 19.33 |
| $SiO_2$, | 18.10 |
| $H_2O$, | 1.67 |
| CuO, | .20 |
| PbO, | .50 |
| Sb, | .66 |
| S, | .08 |
| $Fe_2O_3$, | .58 |
| Ag, | .15 |
| CaO, | 1.32 |
| MgO, | .13 |
| $CO_2$, | 1.33 |
| Na and K, | 1.22 |
| Cl, | .17 |
| | 100.27 |

This ore was roasted under a variety of conditions, with no very satisfactory results. The loss by volatilization was frequently very great. The addition of 5 per cent. of sulphurets did not help the chloridization appreciably. Steam reduced the volatilization of silver to almost nothing. The amount of silver chloridized varied from 30 to 75 per cent.; the amount volatilized, from 50 per cent. to nothing. In the muffle-furnace, chlorinations of 90 per cent. were readily obtained without excessive volatilization.

In amalgamating the ore, a considerable loss in slimes occurred, the silver mineral apparently floating off on the surface of the water. The addition of bluestone, salt, and sulphuric acid in the pans produced some additional chlorination, 81 per cent. being extracted from one charge. The results on a lot of 313.6 kilos. (690 pounds) averaged as follows. Ore assayed 45.4 ounces per ton:

| | Per cent. |
|---|---|
| Loss in roasting, | 17.7 |
| Bullion, | 43.6 |
| Slimes, | 20.9 |
| Tailings, | 17.8 |
| | 100.0 |

## *NOTE ON THE CONTRACTION OF IRON ON SUDDEN COOLING.*

BY HENRY M. HOWE, A.M., S.B., BOSTON, MASS.

IF a bar of wrought iron or steel is suddenly cooled from a bright red-heat, the contraction which then occurs is considerably greater than the expansion previously caused by heating the bar, so that its final length is considerably less than its initial length. Mr. Thomas Wrightson has investigated this phenomenon,* and has shown that not only does this permanent contraction occur on sudden cooling, but, if the heating and cooling be repeated, say fifty times, a further permanent contraction occurs at each successive cooling. In Mr. Wrightson's opinion, this contraction cannot be explained on mechanical grounds, and he ascribes it to some molecular change caused by sudden cooling; but I think that we need not invoke mysterious molecular changes to explain this phenomenon, which appears to me to be due to very simple and purely mechanical action.

Let us consider the cooling as divided into two periods, in the first of which the exterior or skin of the bar becomes almost completely cooled, and hence tends to contract almost to its initial dimensions, while the still hot and plastic interior contracts but little; in the second period the already cool skin remains nearly constant in temperature, and hence tends to contract but little, while the interior cools from a comparatively high temperature to the ordinary temperature, and hence undergoes great contraction.

The excess of the contraction of the skin over that of the interior during the first period tends to make the bar bulge in the middle of its length. This, as well as the decrease of density which occurs, Mr. Wrightson correctly explains. The interior of the bar just sufficed to fill the skin when both were in their initial condition, before being heated at all. At the end of the first period, the volume of the still hot interior is more than the now contracted skin can hold while maintaining its initial shape; and the effect is much the same as when we powerfully blow into a soft India-rubber bag of the shape of the skin of the bar—it *bulges*, and tends to approach the spherical shape, in which the ratio of surface to

* *Journal of the Iron and Steel Institute*, 1879, ii., p. 418.

volume reaches the absolute minimum. This transverse bulging permits the skin to contract longitudinally till, at the end of the first period, when it has almost completely cooled, it has returned nearly to its initial length.*

When we come to the second period, the tendency of the interior to contract as it cools is vigorously opposed by the already cold and contracted exterior, and, as Professor Stokes points out, this resistance to its contraction tends to leave the interior porous; hence the lower specific gravity of the interior of pieces thus cooled.

Now it appears to me, that this struggle between the contracting interior and the comparatively rigid skin is the cause not only of the final porosity of the interior, but also of the permanent longitudinal contraction of the piece as a whole. As the interior contracts, it tends both to draw the skin inwards and to shorten it, exerting a tremendous internal tension on it, and this pull is, of course, resisted by the rigidity of the skin. Now, both the pull of the interior and the resistance of the skin have their effects. The resistance of the skin to a certain extent prevents the interior from contracting to its initial dimensions, while the pull of the interior to a certain extent compresses the skin both longitudinally and transversely, just as a powerful external pressure would. Acting lengthwise, it causes a permanent longitudinal contraction of the skin, just as an upsetting force from without would.†

---

* As this enables the skin to contract longitudinally to an extent closely corresponding to the fall of temperature, so that its length measured around the bulge falls, at the end of the first period, nearly to the initial length, the length of the bar, measured in a straight line, might fall even below its initial length; but this, alone, cannot account for the whole of the contraction of the skin, since in Mr. Wrightson's experiments the length of the skin itself, measured on the bulge, suffered permanent contraction.

† I have already pointed out that the effect of the excess of the external over the internal contraction, during the first period, resembles that of inflating a soft India-rubber bag whose normal shape is that of our bar; the skin, not being large enough to contain the interior while maintaining its own shape, bulges. Now, if we allow the excess of air to escape from our India-rubber bag, its bulged sides draw in, or *collapse*, to an extent the same as that to which they had bulged, which brings the bag back to its initial dimensions. As, owing to the internal cooling during the second period, the interior of our bar tends to contract to its initial volume, one might at first suppose that, as in the case of our India-rubber bag, the sole result would be to counteract the bulging of the first period by an equal amount of collapsing, which would in like manner bring the bar back to its initial dimensions. But bulging and collapsing involve a considerable lengthwise motion and displacement of the internal particles, the bulging forcing them towards the middle of the length of the bar, the collapsing forcing them back again from the middle towards

This compression of the skin by the pull exerted on it by the contracting interior is probably one of the causes of the hardening of iron and steel by sudden cooling, which acts like cold-rolling or cold-hammering; though I believe that hardening is chiefly due to chemical rather than mechanical action.

Mr. Wrightson, as I have already remarked, believes that the permanent contraction is the result "of a change in the distance of the molecules caused by the sudden change of temperature in the successive coolings," while I believe it to be caused by the endeavor of the interior to contract after the skin has returned to approximately its initial dimensions. Now, to test the matter, we may alter the conditions so that, on the one hand, the changes of temperature shall be even more sudden than in Mr. Wrightson's experiments, while, on the other hand, hardly any contraction of the interior shall occur after the skin has completely cooled and contracted. This should afford a crucial test: If Mr. Wrightson be right, we should in this case find still greater longitudinal contraction, caused by the more sudden cooling; if I am right, we should find much less contraction, owing to the almost complete elimination of what I have called the second period of cooling.

These conditions we may obtain by suddenly cooling, not bars so thick that a very great difference exists between the external and internal temperature while they are cooling, but wires so thin that at each instant the temperature is practically uniform throughout their cross-section, so that interior and skin contract at practically the same rate, while at the same time the cooling is much more sudden than in thick bars. From the results given in the accompanying table we see that the $1\frac{1}{8}$ inch square bars experimented on by Mr. Wrightson contracted, under like conditions, about 7 times as much as wire of No. 24 B. W. G., and from about 10 times to about 22 times as much as wires of Nos. 30 and 32 B. W. G., the thin wires contracting much less than the thick.

These results accord with my explanation.

---

the ends; and, during the second period, the interior is so much less plastic than during the first, that its particles resist this longitudinal displacement much more vigorously. Hence, the internal contraction in the second period, unable to fully relieve itself by collapse (*i.e*, by drawing the sides together in the middle of the length of the bar, and forcing the interior from the middle towards the ends), partly results in leaving the interior porous, and partly, as I believe, in compressing the skin lengthwise as well as transversely.

*Contraction of Wrought-iron on Sudden Cooling.*

| Size of bar or wire. | Initial length. | Number of times quenched. | Per cent. of contraction. | Observer. |
|---|---|---|---|---|
| 1⅛ in. square, | 30.05 in. | 5 | 0.76 and 0.66 | Wrightson. |
| | | 15 | 2.26 " 1 86 | |
| Hoop 1⅛ in. sq. | 57.7 in. | 5 | 0.61 | |
| | | 20 | 2.25 | |
| No. 24 B.W.G. | 71. in. | 20 | 0.31* | Howe. |
| No. 30 B.W.G. | 72.75 in. | 20 | 0.09* | |
| No. 32 B.W.G. | 92.75 in. | 5 | 0.067* | |

## *THE PICTOU COAL-FIELD.*

BY HENRY S. POOLE, F. G. S., ASSOC. R. S. M., STELLARTON, NOVA SCOTIA.

THIS field is geologically of much interest. It is small, but with some seams of unusual thickness, the main one being as much as thirty-eight feet thick. The quality of the seams, as also of the associated beds of shale and sandstone, in several instances changes to a remarkable degree within short distances.

The strata dip at inclinations that carry the coal to depths of 3000 feet or more; heavy faults cut up the district, and the New Glasgow conglomerate, of disputed age, separates it from the Upper Carboniferous measures, in which no seams of workable thickness are known. This coal-field offers to the geologist much ground for study and speculation.

The commercial value of the field is affected by its restricted area, the varied quality of its coal, and its advantageous position in the mainland, with railway connection and home markets, offset by the physical difficulties which make the cost of production high.

It has been so long a habit with us to speak of our resources of coal as boundless, that any adverse comments, or insinuations that avoidable loss in working is a national loss, have hitherto fallen on idle ears. While it is not my purpose to underrate the riches we do possess, yet I deem that no good end is served by echoing exaggerated estimates which encourage a national indifference to wasteful

* Part of the apparent contraction may have been due to slight kinking of the wires. We may certainly say that the contraction of the wires was not greater than that given in the Table, and probably somewhat less.

mining and consumption of fuel. It should be clearly understood that these remarks especially apply to Nova Scotia proper; Cape Breton, with fields of unquestionable extent, is not included. The area of its coal-deposits has not been so greatly exaggerated, nor are its less inclined seams subject to the same proportionate waste in working and screening as attends the mining of the more highly inclined beds of the Pictou and Cumberland fields.

The combined area of our coal-lands has frequently been put at 18,000 square miles, equal nearly to the total area of the Province; while a liberal estimate, based on our present knowledge, cannot make the extent of *workable* seams to cover one-fiftieth of that surface. In the Pictou district, so largely is it affected by faults, and the quality of many of the seams being in part reduced below a marketable grade, that an output equal to that of the United Kingdom in the last three years would more than exhaust its resources. And this estimate will not seem surprising when it is known that from an aggregate of 550 acres of seams called 22 and 38 feet thick, barely 10,000 tons per acre were obtained, a quantity that a nine-foot seam of clean coal, under favorable conditions, has produced.

In Cumberland County, also, similar conditions prevent the actual winning of a large proportion of the nominal contents of the seams; and the angle at which they all dip must, within a comparatively short distance, put them beyond the depth at which the coal can be profitably extracted.

In the Pictou field, operations have been in progress for over half a century, and the contrivances used for drawing coal have developed from the simple horse-gin and skip to the modern high-pressure engine, in one instance direct-acting, with cylinders 38 inches, and drums 18 feet in diameter.

The mines railway to the loading-ground is said to have been the second railway built in America. The gauge adopted, 4 feet 8½ inches, has since become the standard, at any rate, on this continent. The district can still show some antiquated appliances, and a working locomotive built as long ago as 1838.

The field has been gone over by the Geological Survey; and in the Report for 1866–69 will be found detailed sections and analyses, to which only passing reference here need be made. It may be considered as divided into three districts: the Central, or Albion; the Western, or Westville; and the Eastern, or Vale; the northern and southern portions being practically of small importance.

The Albion section shows some 4000 feet of measures, the lower

part being conformable millstone grit beds, and the upper part some 1000 feet of unbroken black shales over the coal. These overlying beds are rapidly transformed to the westward, and the black shales give place to sandstones within a mile of the Foord pit, no break intervening. The section is known to contain a number of seams, but only four are thought to be of present workable value. Others of sufficient thickness are, so far as known, of inferior quality.

A downthrow of 1600 feet to the west separates this district from that of Westville, where only the equivalents of three upper seams are exposed. The crops of any lower seams, if they exist, as in the Albion series, have not yet been discovered; the surface is heavily drifted, and perhaps they are cut off by a fault.

The Vale district, on the other side, presents no characteristics in common with the Albion; and the relation of the beds of one series to those of the other is still a matter of dispute. It is in the form of a synclinal trough, with its axis east and west, the seams being thickest on the southern outcrop where they are worked. On the northern side the seams are thinner, and to the west they come to the surface before they reach the fault that separates them from the representatives of the Albion beds.

The coals of this field are non-caking, and are chiefly used for steam and domestic purposes. Some make good coke for iron-furnaces.

In working the beds, as the crops of those opened have already been mined away, and the difficulties that attend the extraction of coal from increasing distances and greater depths present themselves more forcibly, problems come up which make it seem doubtful whether parts of the field can in the future be economically won. The depth to which the dip soon carries the coal, and the tenderness of the overlying measures, requiring in parts close timbering and frequent renewals, entail such expenses for dead work that it becomes a question: How can the seams of minor quality and thickness be profitably worked, not only at shallow depths, but also at the great depths to which in all probability they extend?

The assistance of mechanical engineers must be sought in the solution of this question; and the great advances made of late years seem to indicate that difficulties which but a short time ago appeared insuperable, may be greatly reduced or wholly overcome. Lang's patent supplies a light rope of great strength and durability, so that the increase of dead load due to depth is diminished. A speed of 35 miles an hour in mid-shaft, attained with safety in some deep

pits, shows how loss of time, due to distance, may be much reduced by careful attention to construction. Still, steep inclines, which we have to consider, do not, as ordinarily laid out, offer the same facilities for high speed; and we do not know where to look for good practice that would indicate the limit of speed on inclines of say 15° to 30° for ordinary work, and again, when men are riding. To a depth of 1000 feet, workmen may be got to walk up and down; to greater depths, the tax on their strength would be of some moment. Sooner or later the question of the men riding has to be considered; and if the safe limit of speed be slow, and but few men be allowed to ride together, the loss of time while moving them will be more serious, the deeper the slopes become.

Another difficulty is encountered in dealing with the water that finds its way from crop openings to the deep. As a usual thing, the seams in depth are quite dry and even dusty. Can this water from above be kept back by a barrier of unwrought coal? The Acadia Coal Company are trying the experiment with a barrier of 200 feet, left unwrought right across their area. Above the barrier they have placed, at a vertical depth of 990 feet, a duplex compound engine, which forces water to the surface in one column; and, to remove a small quantity of seepage, they are placing in the deeps a hydraulic engine, which will get its power from the main column. The experience of the Pipe Line Companies in successfully dealing with pressures exceeding 1000 pounds per square inch, and with continuous lengths of many miles of pipe, shows that this system can be made to meet the difficulty, provided the action of the water on the pipes be not very corrosive.

I have referred to the changes that have been found to occur in the character of the strata within very short distances, and instanced the gradual substitution of sandstone for bituminous shales. Similar changes occur in the coal-seams. For instance, a poor coal, within a mile, becomes of superior quality; first coking fairly well, then not coking. Then the coal again deteriorates, and ultimately the bed ceases to be coal. In fact, most if not all of the seams in this district show alterations in quality, and this liability to change, coupled with the smallness of many of the working areas, deters owners from putting down deep pits and costly plants, and leads them to content themselves with extending their crop-slopes, and so winning, lift by lift, thereby adding to the duty of their surface-machinery.

An exception has been made at the Drummond mine, where

single high- and low-pressure cylinders are coupled in an engine placed half-way down the prospective slope to hoist all coal from the deep of them, and deliver to the landing of the surface-engines.

Details of some of the machinery used in this field are given in the Notes* published for the benefit of the members visiting the Pictou field, after the present meeting.

---

* The following are the details referred to:

*Drummond Mine.*—11 to 13 ft. of coal worked; seam dips 15 degrees, worked by slopes, now 2800 ft. long; lifts every 450 ft.; counterbalanced planes every 700 ft.

Ventilation by exhaust fan, 20 ft. by 7 ft.; speed, 52 to 56 per m.; current 100,000 ft. per m.—alternative jet in upcast; lamps, Clanny.

Winding engines, pair 16 in. by 24 in.; V friction geared 2 to 1; drums, 8 ft. dia.; work singly or connected; hauls gross wt. 11,400 lbs.; up 1800 ft. 1 m. 50 sec. lowered by break in 1 m.; W. engine underground; single compound 16 in. and 28 in.; pinion fitted with Fisher's pat. clutch; engine with Joyce's pat. expansion valve-gear (new); steam pipe 5 in.

Pumping.—3 steam pumps, one 18 in. and 8 in., by 36 in.; vertical lift 347 ft.; column 10 in. cast; independent condenser; boilers, steel, 30 ft. by 5.5 ft., 2 flues and egg-end; flash 30 ft. by 3.5 ft.

*Acadia Pit*, at Westville, 3 m. from Stellarton, on I. C. R.

Seam of 10 ft. worked; dip averages 27 deg.; slope 2350 and sinking 600 ft.; extreme vertical depth 1300 ft.

System of working: in lifts of 400 ft. counterbalance planes every 700 ft., with few primary narrow bords, driven in and outbye, followed by prompt pillar working outbye from boundaries.

Ventilation by fan 24 ft. by 8 ft., iron casing; engine 20 in. by 20 in. cut-off; water-gauge, barometer, etc.; Liveing's gas indicator.

Lamps—Mueseler and Marsaut.

Hoisting engine on slope, pair 16 in. cyl., 42 in. stroke; geared 3.5 to 1; drum, 9 ft.; piston speed (usual) 1100 ft. per m.

Pumping.—Duplex compound condensing, 22, 12 in. by 24 in., rams 5.5 in.; column length, 2400 ft., vertical head 990 ft., wrought pipe, tarred, 6 in. upset ends vanishing threads, metal flanges, no leaks; steam-pressure on top 105 lbs., pipe 4 in. covered with infusorial earth from a local deposit; air-feeder added to air-chamber.

Boilers.—Water tube; fuel, culm; grates, perforated plates, and Howe's raker with steam-jet in ashpit.

Screens, double.—Primary, 6 in.; secondary, ¾ in. apart curved; 5 sizes of coal; elevator, revolving and shaking screens; Clarke's jig.

*Albion Mines*, at Stellarton, on I. C. R.—Railway second built in America; locomotives include "Samson," built in 1838, and exhibited at Chicago Exhibition; Main seam, 38 ft. thick; 148 ft. lower, Deep seam, 22 feet thick; Foord Pits, vertical, 900 ft. deep, sunk to Main seam; scene of explosion in 1880; loss of life, 44; workings now full of water; machinery massive; hoisting engine, 38″ cyls. 5 ft. stroke, 18 ft. dia. drum; Cornish pumps, 62 in. cyl., 9 ft. stroke; beam, 34 ft. long, 7 ft deep in the middle; weight, 18 tons; working barrel, 18″ dia.

Air-compressors in course of erection at time of explosion, and now rendered useless in present position; steam cyls., 36″; dia. do., 40″; stroke, 6 ft.; flywheel, 22 ft. dia, weight 20 tons; present workings in lower seams; capacity 1000 tons per

Many of our appliances and mining practices are, we know, open to criticism. In mining the seams we have failed to extract, or have wasted, large quantities of coal; and we have suffered disasters that entailed serious loss of life and property. Therefore, I do not thrust on the notice of the Institute the extent to which we have followed the progress effected elsewhere, but rather ask members to note the weak points of our practice, and our failures, that this visit may lead to subsequent improvement and our better instruction.

I am the more induced to take this ground since, in commenting on this year's disasters in European mines, the American *Engineering and Mining Journal*, which, I take it, though not an organ of the Institute, is in sympathy with it, and expresses opinions which some of its members have formed from their practical experience, spoke as follows: "Our exemption [in Pennsylvania, from frightful calamities] is solely due to the better ventilation and more intelligent supervision exercised. . . . . Well-arranged air-ways and plenty of fresh air, strict discipline, and vigilance, can prevent any such terrible disasters (we hesitate to say accidents) as those recorded."

Now our practices and circumstances somewhat conform to those under criticism, and, as we have hitherto considered that no better could be done with such strata as are often met with in bituminous mines, at depths of 1000 or more feet, we shall be glad to have our errors exposed, and have to remember not only the honor the Institute has done us in visiting our mines, but the good results which followed.

---

diem; ventilation by furnace and fans; the latter 30 ft. dia. by 10 ft. wide; lamps, Mueseler and Clanny; coal used for coking purposes; 104 ovens; bee-hive 10 ft. dia.; average pitch of seam, 22 degrees.

*Vale Mine*, 6 m. E. of New Glasgow, works two seams; McBean, by slope 2400 ft. long; dips 30 to 35 degrees; vertical depth, 1350 ft.

System of working, per levels at 500, 800, 1300, 1800, and 2300 ft. on slope; bords followed by pillar robbing; coal run down in shoots from bord ends; roof very tender.

Ventilation by fan, 30 ft. by 10 ft.; engine, 24 in. by 36 in.; casing of stone, lamps, Marsaut and Clanny.

Winding engines, pair direct, 32 in. by 60 in. stroke; drums, 14 in. dia.; steel ropes, 1.5 in. dia.

Pumps, 30 in., with 7 in. rams by 36 in.; independent condenser; vertical lift, 840 feet; other pumps, 20 in. by 36 in. and 18 in., with 6 in. rams by 24 in.

Boilers, 6 steel; return flue, 30 ft. by 5.5 ft.; 7 egg-end, 30 ft. by 3 ft.

Six-foot seam.—Slope, 1100 ft.; outcrop for 500 left unworked; a new winning ventilated by compression-fan, 16 ft. by 6 ft.; engine, 10 in. by 16 in.

## Discussion.

C. A. Ashburner, Philadelphia, Pa.: The waste of coal due to the variable character of the beds is not so large an item in Pennsylvania, where we have beds from 2½ to 100 feet in thickness, presenting pretty constant characters over large areas. Our waste is largely due to commercial considerations. We throw away what it would cost us too much to save. In bituminous coals the waste is less, say 5 per cent. and upwards, while in some extreme instances in anthracite mining, only 25 to 30 per cent. of the coal in the ground is actually shipped. Many companies, however, do much better. The Delaware and Hudson Canal Company is shipping as much as 60 per cent.

R. P. Rothwell, New York city: Is there trouble from fire-damp in the Pictou districts, and have any explosions been traced to coal-dust as a medium or cause?

E. Gilpin, Jr., Halifax, N. S.: We do have gas in these mines, and there have been some explosions. In one instance, in which several lives were lost, coal-dust was asserted to have been the cause; but on examination of the case, I came to the conclusion that gas had been present, and the coal-dust had served to aggravate the effect. In that mine, we now sprinkle with water the neighborhood of the breasts before firing. Our loss of coal is partly due to the slack demand for coal, to careless mining, and the use of too much powder. Moreover, the steep dip of the seams and the softness of the roof make the pillars crumble rapidly. We employ the bord-and-pillar system.

E. V. D'Invilliers, Philadelphia, Pa.: In Western Pennsylvania, I have found serious changes in the quality of the bituminous coal-beds, similar to those described in this paper. With regard to the fire-damp, I would like to ask whether it is more abundant in the roof or in the floor.

Mr. Gilpin: The gas is everywhere. Bore-holes have been known to give it off steadily for years. As to the irregularity of the beds, it should be observed that the conditions of deposit in the Pictou field appear to have been peculiar. In Cape Breton, on the other hand, the beds are persistent and regular.

## *THE WOLF BENZINE-BURNING SAFETY-LAMP.*

BY E. J. SCHMITZ, COLUMBIA, S. C.

THIS novel safety-lamp, which was first introduced in some of the German coal-mines in 1882, at once attracted general attention in the coal-districts of Europe. Objections which arose during the early stages of its use at the mines have gradually died away with the increase of experience in handling the lamp on the part of the miners, and the continual efforts to perfect it on the part of its inventors. Wolf's lamp has rapidly surpassed all its rivals, and has already a greater distribution on the Continent than any one of its older sisters. In the course of two and a half years, the manufacturers have sold 25,000 of the lamps, besides remodelling several thousand rapeseed-oil lamps.

This great success, which of itself speaks loudly enough as to the superiority of the Wolf benzine-lamp, is corroborated by both official and private reports, which all agree in pronouncing this lamp the best yet brought forward.

It was described in a paper by Mr. Eugene B. Wilson, read at the Chicago meeting of the Institute, in May, 1884,* in which its salient merits were briefly but clearly indicated. Every previous improvement of the original Davy lamp has been directed to one or more of the following main points:

1. Light of greater and more uniform intensity.
2. Freedom from smoke or soot, which clogs the gauze and other parts of the lamp.
3. A greater safety and sensitiveness in the presence of fire-damp.
4. An illuminating material which, satisfying the foregoing conditions, should be also cheap.
5. A lock which could not be opened in the mine by the miner.
6. An arrangement for lighting without opening the lamp.
7. An arrangement for changing the size of the flame in the closed lamp, to supersede the picker, the danger from which is explained in Mr. Wilson's paper, already cited.

It may safely be said that Wolf's lamp was the first to secure all these objects. The adoption of benzine instead of rapeseed-oil (previously the best illuminant) has completely satisfied conditions 1, 2, 3, and 4. Benzine gives a much clearer, stronger, and more uni-

* *Transactions*, vol. xiii., p. 129.

form light; does not clog the lamp with any carbonaceous deposit, and hence affords no occasion for poking the flame; and, moreover, by virtue of this cleanliness and superior luminosity, permits the use of a finer gauze, thus considerably increasing the safety of the lamp, while, at the same time, it affords a sensitive indication of the presence of fire-damp, since, when the latter has increased to a dangerous percentage, the light goes out. Yet, on the other hand, it will burn in an atmosphere contaminated with black-damp (carbonic acid) long after an oil-lamp would have been extinguished for want of oxygen. To all these advantages is added that of economy, the cost of benzine being only half that of oil. As to points 5, 6, and 7, the Wolf lamp has a lock which can be opened only by the magnet kept for the purpose by the proper official; it can be lighted with ease and certainty by the percussion-tape without opening it; and no picker is needed either to clean or to adjust the wick, cleaning being unnecessary, and the wick being raised or lowered by means of a screw.

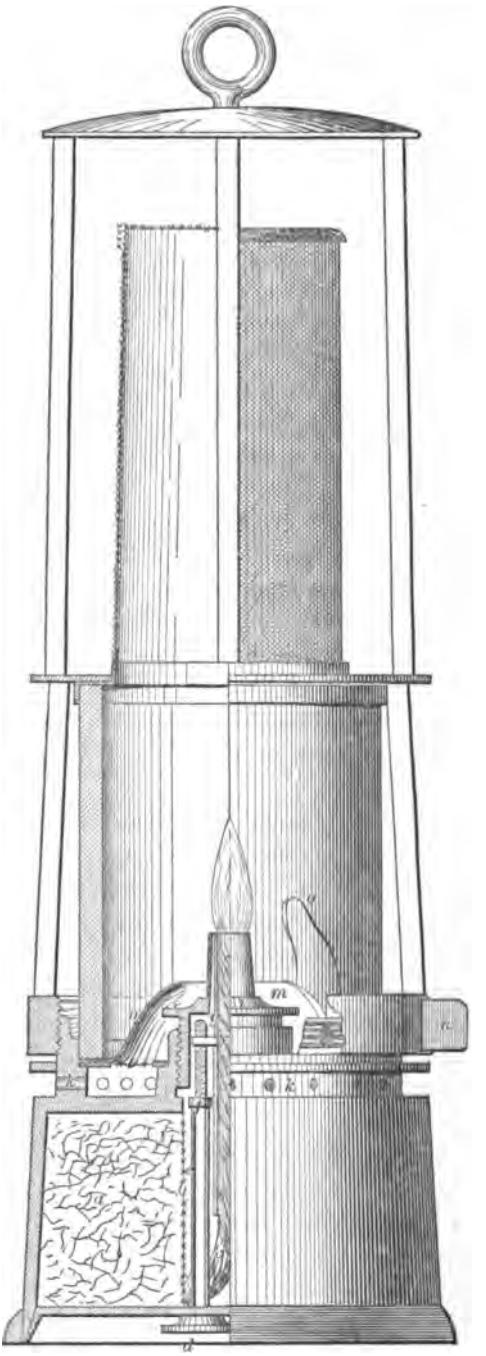
*Description of the Lamp.*—Wolf's lamp is manufactured in two forms, which we may call No. 1 and No. 2. No. 1, which is the most economical of the two, conveys the air from below to the flame, while in No. 2 the air enters from above through the wire gauze. The conveyance of air from below to the flame, which from the chemical standpoint is without doubt the better way, is also, as the experiments of the Safety-Lamp Investigation Commission* have clearly demonstrated, superior in safety; and I therefore give in Fig. 1 a lamp of system No. 1.

The body of the lamp, *a*, contains the benzine and is packed with cotton or mineral wool to prevent spilling. Through a gauze cylinder, *a* is connected with *c*, the space holding the wick. The screw, *d*, passing through the pipe, *e*, carries the collar, *f*, and has connection with the wick-picker, *g*, which fits exactly in the case, *i*, so that the benzine gases can only pass upwards through the wick. The air enters through the ring, *k*, and the wire gauze, *l*; and the screen, *m*, directs the air to the flame. The locking-device is in the case, *n*; and *o* represents the upper end of the chimney, in which the lighting-device is placed.

Fig. 2 shows the lighting-device in full size. The manner in which it is operated in the lamp is shown better in the illustration of Mr. Wilson's paper, already cited, than in Fig. 1 accompanying this paper. This device has proved so advantageous that no lamps

* *Jahrbuch für Berg- und Hüttenwesen des Königreichs Sachsen*, 1884.

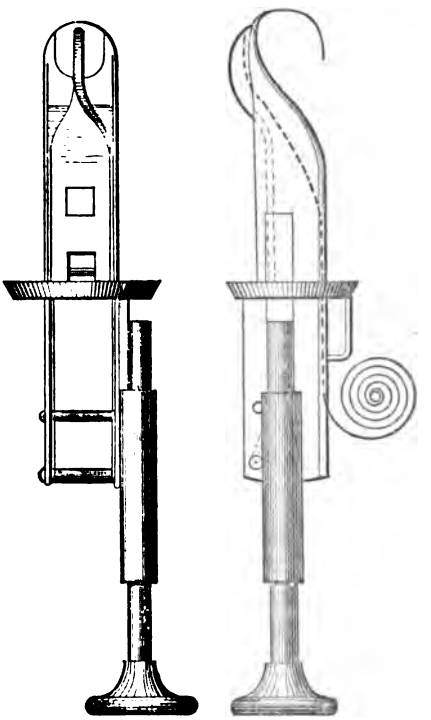
FIG. 1.



Wolf's Benzine-Burning Safety-Lamp. ⅓ of natural size.

without this attachment are now wanted, and thousands of oil-lamps have already had it applied to them. A priming-strap or percussion-tape (costing only a few cents) being inserted, the lamp can be lit about 75 times before renewal is necessary. This device, besides its absolute safety, affords a very considerable economy of time and money. The miner is no longer compelled to leave the shaft, in the

FIG. 2.



Device for Lighting with Percussion Tape. Full size.

event of his lamp being extinguished, for the purpose of getting a reserve lamp from the lamp-stores; and the management thus saves the cost of all the reserve lamps.

The magnetic lock in use on Wolf's lamp belongs to the so-called "direct-acting" class, and is one of the best yet devised. It is represented in Fig. 3, and consists in an iron anchor, turning upon an axis, and held by a spring in a position which prevents the unscrewing of the lamp-body. The force of this spring, which is inaccessible from the outside, must be overcome by means of a strong magnet before the lamp can be opened.

To complete the plant for the lighting of mines, the manufacturers of this lamp construct a filling-apparatus, which consists of a large sheet-iron reservoir and a small glass vessel. The capacity of the latter corresponds with that of the lamp, and it is shut off from the reservoir or tank, while the lamp is filled from it.

There is also a testing-apparatus, which enables managers of mines to prove at any time whether the lamps are really in good order or are leaking, and therefore unsafe. This apparatus consists of three

FIG. 3.

Magnetic Lock. Full size.

distinct and connected vessels. The first and largest vessel is composed of two cylinders, fitting in each other, open on opposite ends, and partly filled with water. Its purpose is to create a current of air, by virtue of the weight of the upper cylinder. The air enters into a second vessel with a number of fish-bellied sheet-iron partitions, filled with any suitable absorbing material, which receives benzine from a small tank at the upper end of the vessel. The third vessel or cylinder has a glass window and contains a coil of pipe provided with small apertures. Within this coil the burning lamp is placed. The current of atmospheric air produced in vessel No. 1 enters vessel No. 2 at the bottom, and passing upwards absorbs benzine from the material impregnated with it, thus forming a

"benzine-gas," which escapes from the upper portion of vessel No. 2, and enters No. 3 at the bottom. Here it passes through the pipe of the coil which surrounds the lamp, escapes through the small apertures in jets directed at the lamp, and ignites in case the lamp is not tight.

*Official Reports upon Wolf's Safety-Lamp.*—The report of the "Safety-Lamp Investigation Commission," appointed for Saxony, and presided over by Professor Kreischer and Bergrath Dr. Winkler, of the *Bergakademie* at Freiberg, was published in the *Jahrbuch* for 1884, already cited. It is without doubt the most thorough of recent reports upon this subject. The lamps brought into a competitive test before this Commission were the following:

1. Wolf's Safety-Lamp (benzine-burning), Nos. 1 and 2.
2. Oil Safety-Lamp (Rabe's system), conveying the air from below.
3. Oil Safety-Lamp (Schoendorff's system, Koetz's patent), with air-conveyance from above and magnetic locking-device.
4. Colza (Rape-seed) Oil and Petroleum Safety-Lamp (Winkler's system), with air-conveyance from below.

During the first trials, a Davy and a Stephenson lamp (from the manufacturer, E. Thomas, of Aberdare, England) were also tested; but these were afterwards set aside, because in photometric power, and in usefulness as indicators for the detection of fire-damp, they were too far behind the others for practical comparison. The Müseler lamp was also excluded, because, by reason of its sheet-iron chimney, it could not well have much value as an indicator.

From the report of this Commission, I translate the following passages concerning the Wolf lamp.

Speaking of the small and irregular light given by the old oil-lamps, the Commission observes that without doubt miners are, for this reason, frequently compelled to open their lamps in order to clean the wick and enlarge the flame, and adds that these difficulties could not have been overcome in lamps using greasy and slow-flowing oils which yield carbonaceous secretions. Therefore it had been tried, years ago, to introduce the burning of a mixture of colza-oil and petroleum in safety-lamps, but without much success. The Commission adds that in this respect only very lately a thorough improvement has been brought forward, consisting in the use of benzine in the Wolf lamp, which has placed all other illuminating materials for safety-lamps in the back-ground, especially as the benzine has been shown to be free from danger in a well-constructed lamp.

An account is given of the tests made by the Commission to determine to what extent benzine used in Wolf's lamp might be liable to explosions. That a lamp producing such a strong light as the benzine lamp does, and so distinguished besides for cleanliness and convenience, has met with great favor, is easy to understand. But there existed one uncertainty about the benzine-lamp which had to be officially settled; and that was, whether a lighting-material like benzine, which consists of oils boiling at from 50°–130° C., and the vapor of which combines with air to a very inflammable and explosive mixture, would not produce new danger for the mines. These fears have not been confirmed. Already, in 1882, Mr. Menzel, mining inspector in Zwickau, made, by order of the Royal Mining Office, a number of experiments in this direction, and proved that benzine, burning in Wolf's lamp, was not at all dangerous. This was subsequently confirmed by the numerous and careful tests made by the Commission. Very instructive were a number of trials made with the Wolf lamp with air-conveyance from below (System No. 1), which were burned for hours in a glass cylinder, into which a mixture of common illuminating gas and air was conducted. An "aureole" was thus formed which filled the entire inner gauze space and brought the benzine to boiling, without being able to make the gauze red-hot.

With regard to the consumption of benzine in Wolf's lamp, the report furnishes the following data:

The height of the flame in Wolf's benzine and the colza-oil and petroleum lamp during the tests was 25 mm.; in the colza-oil lamp it was 20 mm.

The cost per hour for the different lamps was in *Pfennigen* (the pfennig or farthing being $\frac{1}{100}$ of a mark, and the mark being worth between twenty-four and twenty-five cents):

| | Pfennige. |
|---|---|
| Wolf's benzine-lamp No. 1 | = 0.161 |
| Wolf's benzine-lamp No. 2 | = 0.157 |
| Colza-oil lamp with air-conveyance from above | = 0 325 |
| Colza-oil lamp with air-conveyance from below | = 0.221 |
| Colza-oil and petroleum lamp with air-conveyance from below | = 0.403 |

The photometric power of the different lamps was as follows:

| | Height of Flame. | Cost per Hour. | Photometric Power. |
|---|---|---|---|
| Wolf's benzine-lamp No. 1, | 25 mm. | 0.161 | 54.90 per cent. |
| Wolf's benzine-lamp No. 2, | 25 mm. | 0.157 | 42.83 " |
| Colza-oil lamp No. 1, | 20 mm. | 0.325 | 33.44 " |
| Colza-oil lamp No. 2, | (15 mm., not normal) | 0.221 | 25.08 " |
| Colza-oil and petroleum lamp, | 25 mm. | 0.403 | 62.33 " |

The lighting power of a normal flame of the German *Vereins-kerze* will cost per hour in the different lamps:

| | Pfennige. | Relative Cost. |
|---|---|---|
| Wolf's benzine-lamp No. 1, | 0.293 | 1.00 |
| Wolf's benzine-lamp No. 2, | 0.367 | 1.252 |
| Colza-oil lamp No. 1, | 0.975 | 3.328 |
| Colza-oil lamp No. 2, | 0.861 | 2.940 |
| Colza-oil and petroleum lamp, | 0.646 | 2.505 |

These figures demonstrate that the Wolf benzine-lamp No. 1 (with air conveyance from below) gives the cheapest light, costing per candle-power only from 30 to 40 per cent. as much as the colza-oil lamps.

The tests made with this lamp, to ascertain its relations to gas mixtures with different percentages of fire-damp, gave the following results:

The normal flame of the lamp is lengthened already several millimeters in a gas-mixture with 1 per cent. of fire-damp, and can, therefore, to a limited extent, be used to indicate even such a small percentage of fire-damp. At 3 per cent. of fire-damp, the flame is lengthened more than one-half of its original height, and at 4 per cent. the height is more than doubled. Hence the normal flame of Wolf's benzine-lamp gives, for fire-damp mixtures which are not inflammable at all, very reliable and easily perceptible signs. At 5 to 6 per cent. fire-damp, these signs show themselves in a still higher degree, and at 7 per cent. the light goes out. In all stronger gas-mixtures of fire-damp, the phenomena of flame-extinction and the aureoles thereby caused give certain tests for the percentages of fire-damp.

A second and far more reliable test for fire-damp is given by the changes which take place in the aureole of the *reduced* flame. At 1 per cent. of fire-damp the aureole is small, but it develops rapidly, and is at 2 per cent. already closed at the top and about 10 mm. long.

This appearance is clearly visible, and can be produced by any unskilled miner, if he has only been shown the occurrence once, and is able to turn the set-screw slowly.

From 2 per cent. upwards, the aureole grows at first in proportion to the percentage of fire-damp, and is at 4 per cent. already 45 mm. high, while at 5 per cent. it reaches the upper end of the gauze. Between 6 and 7 per cent. is the limit, as well for the normal flame as for the aureole. Both are extinguished at 7 per cent. In the

same region we have to look for the point of inflammability of fire-damp mixtures. The Commission says: "*The Wolf benzine-lamp is extinguished, as we observe, as soon as the lamp is brought into contact with inflammable, and, therefore, dangerous gas-mixtures.*" In stronger gas-mixtures, far above the minimum of explosibility, neither flame nor aureole can exist. Only at 15 per cent. the aureole appears again.

The Wolf benzine-lamp No. 2 does not show the increase in length of the normal flame or of the aureole so much as No. 1. No. 1 is, therefore, a more useful indicator. But in stronger gas-mixtures the aureole of No. 2 will remain in most cases and have a constant and characteristic form (as for instance at 10 per cent. fire-damp); hence No. 2 will do good service in stronger gas-mixtures, in which No. 1 will go out.

No. 2 shares this tendency to form a more permanent aureole with those colza-oil lamps which also convey the air from above through the wire gauze. As these aureoles remaining in the lamps are the reason of the red heat of the wire gauze, which is liable to cause the ignition of the fire-damp outside, it is well understood that lamps forming such permanent aureoles are more dangerous than those in which the aureoles are extinguished. It appears, therefore, contrary to the opinion very generally held, that the safety-lamps with air-conveyance from above through the wire gauze are a great deal more dangerous than those with air-conveyance from below.

The Wolf magnetic locking-device, according to the report of the Investigating Commission, has resisted, up to this time, all efforts of the miners to open the lamp, by beating and throwing it about, etc.

It is further remarked in the report of the Commission that the wick-regulation in this lamp for the enlarging and reducing of the flame is an excellent one, and that Wolf's safety-lamp stands, in this particular also, at the head of all the lamps tested.

The lighting-device works without fail, and has been brought to such a state of perfection that it is very seldom that one of the percussion-wafers is missing.

Sudden shocks applied to the lamp in a cold state, just after it is lighted, do not affect it more than they do any colza-oil lamp; while such shocks when applied to the benzine-lamp in a warm state do not nearly so often extinguish the light, as is the case with any oil-lamp.

## *THE PRODUCT AND EXHAUSTION OF THE OIL-REGIONS OF PENNSYLVANIA AND NEW YORK.*

BY CHARLES A. ASHBURNER, GEOLOGIST IN CHARGE PENNSYLVANIA SURVEY, PHILADELPHIA, PA.

THE petroleum industry of western Pennsylvania and southwestern New York has been one of phenomenal development. Greater and more sudden fluctuations have occurred in the price* of crude oil, and in all the collateral interests dependent upon its production, than in the case of any other mineral product which has been extensively exploited in the United States. This was more particularly so from the commencement of drilling for oil in 1859 down to the end of 1877. The experience gained during these early years has enabled the oil men to operate more intelligently since; the business is not now attended with the hazardous risks with which it is generally credited.

The most important questions connected with the oil industry are those of (*a*) the oil-supply, and (*b*) the possible ultimate exhaustion of the field. Since 1876 my attention has been directed to the study of the statistics of the product of the oil regions. In January, 1880, in order to show some interesting points connected with these questions, I prepared a graphic chart which was used to illustrate a lecture on petroleum delivered before the Franklin Institute. This chart was afterwards reconstructed in two distinct forms for publication in the census report on *Petroleum and its Products*. These latter I have redrawn in a condensed form, and have extended them to include the statistics up to 1885, for publication in the *Transactions* of the Institute, in conjunction with a map of the oil-regions prepared by Mr. John F. Carll and myself. It is hoped that these illustrations will be found interesting to the members of the Institute, and of practical utility to oil-men, without any extended discussion, since it is my desire to make only such brief references to them and give such additional detailed facts as may serve to make the prominent features understood.

* The average price of crude oil for January, 1863, was ten cents a barrel. This was the lowest monthly average ever attained; the highest monthly average was $12.12½ per barrel for July, 1864. The lowest yearly average was 78¾ cents for 1882, and the highest $9.87½ for 1864. The average price of the entire product to January, 1885 (260,990,435 barrels), has been $1.63¼. A barrel of petroleum is always considered to contain forty-two gallons.

For convenience of reference, during the past few years, the individual oil-pools of the region have been grouped under six prominent districts, as follows:

1. Allegany district includes the Richburg and several small outlying pools in Allegany County, N. Y. The area which has proved productive oil-territory is 31 square miles,* of which the Richburg field embraces an area of 28 square miles.

The Allegany district up to January, 1885, produced 15,000,000 barrels, an average of about 419,000 barrels per square mile.

2. Bradford district embraces the oil-pools in central and northern McKean County, Pa., and southern Cattaraugus County, N. Y. The area of productive territory in this district is 133 square miles, 121 square miles of which is included within the Bradford field proper. The sand from which the oil in the Allegany and Bradford districts is obtained consists of a gray, black, dark-brown or chocolate-brown colored sand of about the coarseness of the ordinary beach-sand of the New Jersey coast.

The interval between the top of the oil-sand and the bottom of the Olean conglomerate (the bottom member of the Pottsville conglomerate, No. XII., or Millstone grit), which is one of the most persistent and best recognized geological horizons in western Pennsylvania, is, at Bradford, 1775 feet.

The oil obtained is dark amber-green and, occasionally, black. Its gravity is generally slightly greater than that of the oil mostly obtained throughout the Venango and Butler districts, which is generally stated at about 48 degrees.

The Bradford district up to January, 1885, produced 109,000,000 barrels, an average of about 820,000 barrels per square mile.

3. The Warren district comprises the oil-pools in eastern Warren County and northeastern Forest County, Pa. The total area of the productive territory in this district is 35 square miles. The two largest pools are the Clarendon, in Warren County, which covers

* The territories of which the areas are given here were defined by arbitrary lines, drawn to include all the surface where producing wells have been obtained or which was known, from actual drilling up to January, 1885, to be underlaid with oil. All the individual pools are shown on the accompanying map; the areas of some of them have been slightly exaggerated in order that they might be observed on a scale of twenty-five miles to one inch. A map on a scale of six miles to one inch, showing, with approximate exactness the areas of the pools, will appear in the annual report for 1885 of the Second Geological Survey of Pennsylvania. The total area of all the productive oil-territory in Pennsylvania prior to 1885 was 369 square miles.

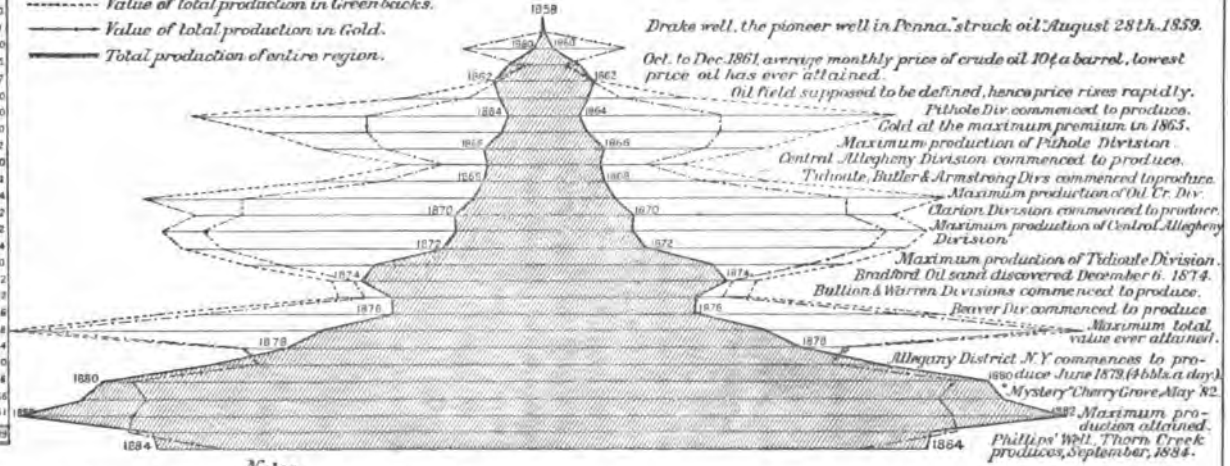
# *Chart showing the annual production of Petroleum in the Oil Regions of Pennsylvania and Southern New York since its discovery, with the values of production in Currency and in Gold,*

*by Charles A. Ashburner.*

| YEAR | AVERAGE YEARLY PRICE | TOTAL ANNUAL VALUE OF PRODUCTION IN GREENBACKS. |
|---|---|---|
| 1859 | 20.00 | 40,000.00 |
| 1860 | 9.60 | 4,800,000.00 |
| 1861 | .49 | 1,035,668.41 |
| 1862 | 1.05 | 3,209,524.50 |
| 1863 | 3.15 | 8,225,623.35 |
| 1864 | 9.97½ | 20,896,576.37 |
| 1865 | 6.59 | 15,459,843.00 |
| 1866 | 3.74 | 13,455,398.00 |
| 1867 | 2.41 | 8,068,993.60 |
| 1868 | 3.62½ | 13,217,174.12 |
| 1869 | 5.63 | 23,730,450.00 |
| 1870 | 3.89 | 20,503,753.63 |
| 1871 | 4.34 | 22,331,179.34 |
| 1872 | 3.64 | 21,440,502.72 |
| 1873 | 1.82 | 10,100,464.12 |
| 1874 | 1.17 | 12,647,526.84 |
| 1875 | 1.35 | 11,863,133.10 |
| 1876 | 2.56 | 22,992,821.62 |
| 1877 | 2.42 | 31,788,565.81 |
| 1878 | 1.19 | 16,044,519.76 |
| 1879 | .85 | 17,210,707.58 |
| 1880 | .94 | 24,500,657.84 |
| 1881 | .85 | 23,457,344.90 |
| 1882 | .79 | 24,381,327.48 |
| 1883 | 1.05 | 24,458,971.36 |
| 1884 | .83 | 18,981,394.51 |
| | | 426,200,002.09 |

*Legend.*

- *Value of total production in Greenbacks.*
- *Value of total production in Gold.*
- *Total production of entire region.*




*Notes.*

*The total annual value was obtained by multiplying the total production by the average yearly price. The average yearly premium on gold was obtained by taking an average of the highest, lowest, opening and closing price of gold in currency for each month in the year.*

*Based on Stowell's statistics.*

*Scale.*

1000000 0 2000000 4000000 6000000 8000000 10,000,000 BARRELS OR DOLLARS.

O.B.A.

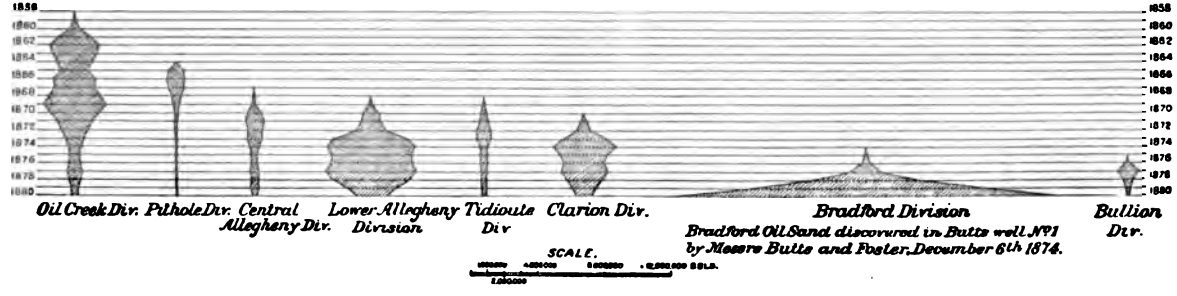
an area of about 14 square miles, and the Cooper and Sheffield, partly in Warren and partly in Forest, covering an area of 9 square miles.

The oil in this district comes from sands of varying geological horizons, having somewhat the general appearance of the Bradford and Allegany sand, but frequently coarser-grained and sometimes containing small pebbles, which latter I have never known to have been found in the sands of the other two districts. According to Mr. Carll, the depths of the Warren district oil-sands below the Olean conglomerate are as follows: North Warren sand, 1100 feet; Warren third sand, 1300 feet; Clarendon third sand, 1450 feet; Cherry Grove third sand, 1625 feet; and Cooper (Forest County) third sand, 1850 feet. The Cooper sand is supposed to occupy the same geological horizon as the Bradford and Allegany sand. The Allegany, Bradford, and Warren district sands I believe to be of Chemung (Devonian) age. The oils from the different Warren pools vary greatly in color and gravity; but they are generally spoken of as amber oils. The Warren district, up to January, 1885, produced 12,000,000 barrels, an average of about 343,000 barrels per square mile.

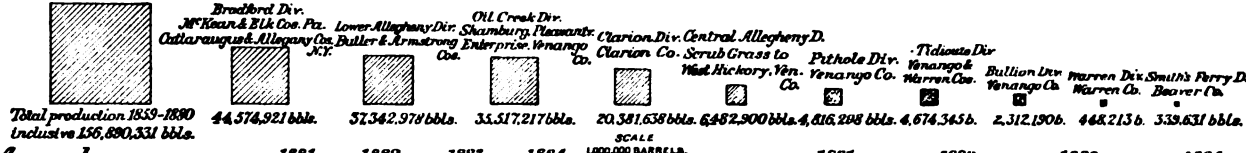
4. The Venango district, which was the scene of all the earlier oil developments, includes 40 distinct and well-recognized oil-pools, the total area of which is 65 square miles, the largest pool being that lying between Oil City on the south and Pleasantville on the north, covering an area of 28 square miles. No one of the other pools exceeds an area of 5 square miles, which is about the productive territory covered by the Tidioute and Triumph pool in southwestern Warren County, and the Franklin pool in western Venango County. The oil of this district is obtained from three principal sand-beds, known respectively as the first, second, and third oil-sands, contained within an interval of 350 feet. The first sand, which is the uppermost one of the three, lies about 450 feet below the base of the Olean conglomerate. The Venango sands I believe to belong to the Catskill (Devonian) formation No. IX. These oil-sands were the first discovered in Pennsylvania; and drillers from this field, operating in other districts, have designated the sands which were found in the new districts as the first, second, and third sands, irrespective of their relative geological position. The Venango sands generally consist of a white, gray or yellow pebble-rock. The pebbles are water-worn, are sometimes as large as hazelnuts, and are loosely cemented together, and generally bedded in fine sand. The sand in

# Chart showing the annual production and Development of the individual districts in the Oil Regions of Pennsylvania and Southern New York.

by Charles A. Ashburner.




## Proportional production of the individual districts.




**Annual Production 1881 to 1884 inclusive**

| | 1881 | 1882 | 1883 | 1884 |
|---|---|---|---|---|
| Allegany | 681,509 | 7,045,731 | 4,003,590 | 3,231,357 |
| Bradford | 22,945,069 | 16,792,308 | 13,305,266 | 11,444,773 |
| Warren | 220,795 | 3,814,071 | 3,152,313 | 4,211,552 |
| Lower | 3,480,686 | 3,259,367 | 2,667,220 | 3,844,527 |

Total production of Oil Regions to 1885, 260,990,435 barrels. Based on Stowell's statistics.

C.A.A.

this district has not as regular or as homogeneous a character, over extended areas, as in the Bradford and Allegany fields, where the sands are phenomenal in this respect; consequently, the risk of obtaining dry holes and wells of variable production in the Venango district has always been greater than in the Bradford and Allegany. The oils are generally green, frequently black, and in some instances amber. The gravity varies from 30 to 51 degrees, 48 degrees being about the average gravity of the oil obtained from the third sand, which is the greatest producer. The Venango district up to January, 1885, has produced about 55,000,000* barrels, an average of about 846,000 barrels per square mile.

5. The Butler district has been made to include the oil-pools in Butler and Clarion Counties and southeastern Venango County. The total area of the oil-pools is 84 square miles, of which at least 76 square miles are embraced in the Clarion, Butler and Armstrong field, and the Butler cross-belt, The oil in this district comes from the same group of oil-sands as in the Venango district. Certain splits occur in the sands, however, which have not been discovered in the Venango district. The character of the sands and the oils which they produce vary much the same as in the Venango district, the individual oil or sand in one district having a counterpart in the other district. The Butler district, up to January, 1885, produced about 69,000,000 barrels, an average of about 821,000 barrels per square mile.

6. The Beaver district includes the two principal oil-pools known as Slippery Rock and Smith's Ferry. The former pool and that

* The Venango district, up to June, 1882, produced an aggregate of 53,569,000 barrels. Since that date the reported production of this district has been included in that of the Butler and Beaver districts, so that the estimated aggregate product of the Venango, the Butler, and the Beaver districts respectively, to 1885, is only approximate, although the total product of the three districts, composing what is now known as the Lower Field, has been obtained from actual reports. All the figures given in this paper have been based upon the statistics which have been published monthly in Stowell's *Petroleum Reporter*, with one exception; the aggregate production to 1885 of the Beaver district, which has been compiled from various sources, is greater than that given either in the *Petroleum Reporter* or on the accompanying chart, showing the annual production of the individual districts. Mr. Carll has prepared a "Statistical Chart of the Oil Production in Pennsylvania and New York from 1859 to 1882," which is published in the "Survey Report on Warren County." The statistics contained on Mr. Carll's chart have been collected by him from various sources; I believe them to be more accurate in detail than any which have ever been published, they differ but little in their general conclusions from those reported by Mr. S. H. Stowell, which latter have been much more convenient to use in this connection.

portion of the latter east of the Pennsylvania State line cover an area of about 16 square miles; the area of the Slippery Rock pool being about one-fourth that of the Pennsylvania portion of the Smith's Ferry pool. In both of these pools heavy oil is obtained from the representative of the Pottsville conglomerate, No. XII., and amber oil from the Berea grit in the Sub-carboniferous series. The production of oil in this district up to January, 1885, was about 1,000,000 barrels, an average of 62,000 barrels per square mile.

Outside of the limits of these districts a small amount of oil has been found in isolated pools to the south and southeast of the Beaver and Butler districts; at Mt. Nebo, in the vicinity of Pittsburgh; in the vicinity of Pleasant Unity, Westmoreland County; near the mouth of Dunlap Creek in Fayette County; along Whiteley Creek, west of Mapletown, and along Dunkard Creek north of Fairview, both in Green County; and in the vicinity of Washington, in Washington County.

That the general boundaries of the oil-regions of Pennsylvania are now well established, there is but little doubt; and that all the sands in which oil will ever be found in paying quantities are known and have been drilled through at different localities in the oil-regions seems quite certain, so that we can have no reasonable expectation that any new and extensive field will be found which could compare in area or in the amount of oil to be obtained from it with the Butler, Clarion, and Armstrong pool, the Oil City and Pleasantville pool, the great Bradford pool, or the Allegany pool. Prof. Lesley, in speaking of this subject in January, 1883, says: "It is certain that petroleum is not now being produced in Devonian rocks by distillation or otherwise. What has been stored up can be got out. When the reservoirs are exhausted, there will be an end of it. The discovery of a few more pools of two or three million barrels each can make little difference in the general result." Mr. Carll, in June of the same year, writes: "There are not at present any reasonable ground for anticipating the discovery of new fields which will add enough to the declining products of the old, to enable the output to keep pace with the shipments or consumption." These results, foreshadowed by Prof. Lesley and Mr. Carll, were not generally appreciated until the latter part of 1883.

The irregular but, in the long run, steady decline in the daily production of petroleum from July, 1882, when the maximum average daily production for any one month was attained (105,102 barrels) is now generally realized. The production for any one month, or any

one year may be increased very materially, over what it is at present, by renewed activity in drilling wells within the general confines of the oil region, or by working over old territory under the stimulation of a hungry market and high prices; but such an increase in production can only be of limited duration, since there is nothing to hope for during a decade of years but a progressive decline. In 1884, the total production of the region was 22,732,209 barrels, which* was nearly one million barrels less than the shipments; during the first eight months of the present year the production has fallen 2,022,355 barrels within the shipments. At the end of August, 1884, the maximum of stocks ever held in the oil regions was attained (39,084,561 barrels); two weeks ago (September 1, 1885), the stocks had declined to 35,343,771 barrels.

It is estimated that in July, 1883, there were in the region, 17,100 producing wells, the average daily product of which was 3.8 barrels. In July, 1884, there were 21,844 producing wells, and the average daily product was 3 barrels; and in July of this year it is estimated that there were 22,524 producing wells, the average daily product being 2.5 barrels.

A defined territory, a product inadequate to meet the demand of the market for the past eighteen months, a growing market and rapidly diminishing stocks; an increasing number of drilling and producing wells, and a rapidly falling daily average product per well, are all significant signs of a certain decline in a great industry; and yet the average price of crude oil per barrel for the month of July, 1885 (92½ cents) was 13¼ cents less than the average price for the entire year of 1883, and only 9 cents more than the average price for 1884. In the month of August, 1885, the average price per barrel had risen to $1.00¼. Although this is a great advance over the price for the preceding months of the year (January, $0.70⅞, February, $0.72⅜, March, $0.80⅜, April, $0.78½, May, 0.79, June, $0.82), yet it is not as great as might reasonably be expected in view of the conditions of the petroleum industry referred to.

At the Washington meeting of the Institute, held in February, 1882, the late Henry E. Wrigley read a paper on the amount of oil remaining in Pennsylvania and New York (*Transactions*, X., 354), in which he gave the area of the oil-territory, the amount of oil produced per

* The total production for 1884, as stated by the *Petroleum Reporter*, was 24,772,209 barrels; the total production given above, like all the totals made use of in this paper, was computed from the individual monthly reports, and are believed to be correct.

square mile, and estimates of the amount of territory yet to be drilled over, and of the quantity of oil which could be expected. I do not wish to make special criticism of Mr. Wrigley's statements or conclusions, but merely to say that facts did not sustain his statements, and I never accepted his conclusions. The mystery with which the operations in the oil-regions have been conducted during the last ten years, makes it extremely difficult to gather authentic particulars from the drillers or producers; and if it were not for the valuable services which Mr. Carll has rendered, as far as the records of oil-wells and the geology of the region is concerned, and that which has been rendered by Mr. Stowell in the collection and publication of statistics, it would be impossible, even now, to arrive at any conclusions bearing on the questions to which I have presumed to make brief reference in this paper.

The geologists of the Pennsylvania Survey, and a few of the oil-operators who have given the subject a careful consideration, are united in believing that the general confines of the territory are defined, and it is admitted that it is in vain to drill wells, as has been done during the past year in Lycoming and Chester counties, where none of the conditions under which oil has been obtained in Pennsylvania are to be found. The fact must not be lost sight of, however, that some of the individual oil-sands have been explored within limited areas only of the oil-region proper. For instance, the Bradford sand, which has been found so prolific in the Allegany and Bradford districts over an extent of territory 42 miles in length, and in places 15 miles in breadth, owing to its great depth below the surface, and the procurement of oil at higher horizons, has not been thoroughly explored in districts to the southwest, although this is the producing sand in the Cooper pool, and in several instances wells have pierced its horizon.

In February, 1878, in a paper which I read before the Engineers' Club of Philadelphia, on the oil-sands of Pennsylvania, I referred to the discovery of the Smethport oil-sand in McKean county, about 360 feet below the bottom of the Bradford oil-sand. What the possibilities of obtaining oil at this horizon anywhere in the oil-region are, it is impossible at present to state. The horizon of this sand has been pierced by several wells, and a small show of oil has been found; but additional wells drilled for exploring this sand may prove complete failures. It is a noted fact that no two oil-sands, one immediately above the other, have been great producers over the same extended area. I have called attention to these facts as

those which may influence the extent of the production of oil in Pennsylvania and New York in the future.

In 1882 Mr. Wrigley stated that the total production to the commencement of that year had been 154,000,000 barrels, and that but 96,000,000 barrels of oil remained to be got. Up to the commencement of the present year the total product of the oil-regions was 261,000,000 barrels, as shown by the accompanying chart. That the product has passed its meridian, there is no question, but what the total aggregate for the future will be, it would be folly to estimate. That the product per well will be less, and the cost of producing one barrel much more than in the past, experience would seem to prove. These, with other collateral facts connected with the production, manufacture, and consumption of the product will make the exhaustion of the field a gradual one; and it is probable that long before every barrel of oil shall have been taken out of the oil-sands, the cost of production per barrel will be so great, that the oil-men's occupation in Pennsylvania and New York will be gone. It is hardly probable that the Japanese practice of excavating a vertical shaft 600 feet in depth to obtain a few gallons of oil a day will ever prove a profitable enterprise in America.

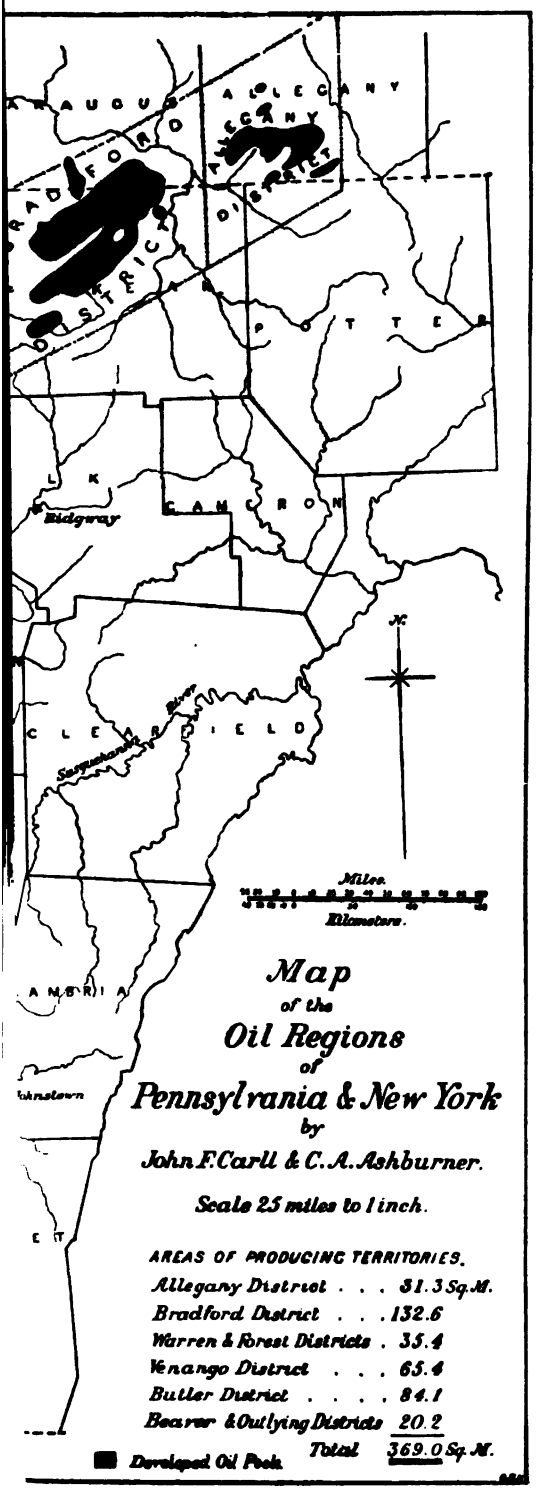
---

## *THE GEOLOGY OF NATURAL GAS.*

BY CHARLES A. ASHBURNER, GEOLOGIST IN CHARGE PENNSYLVANIA SURVEY, PHILADELPHIA, PA.

THE existence of natural gas-springs in Pennsylvania and the adjoining States west of the crest of the Allegheny Mountains was known to the earliest settlers. Possibly the first gas obtained from a well was at Fredonia, Chautauqua County, N. Y., where a well was sunk on the bank of Canadaway Creek, near the Main Street bridge, in 1821, and sufficient gas obtained for 30 burners, the inn having been illuminated by the gas when General Lafayette passed through the village about 1824. In 1858 another well was drilled, which supplied 200 burners. A still larger one was drilled to a depth of 1200 feet in 1871. According to Mr. E. J. Crissey, Secretary of the Fredonia Natural Gas Light Company, the average monthly supply of these wells in 1880 was 110,000 cubic feet.

Since 1859, when the drilling of oil-wells in Western Pennsyl-


ALLEGANY
ALLEGANY
DISTRICT
POTTER
CAMERON
Ridgway
CLEARFIELD
Susquehanna River
Miles.
Kilometers.
CAMBRIA
Johnstown
Map
of the
Oil Regions
of
Pennsylvania & New York
by
John F. Carll & C. A. Ashburner.
Scale 25 miles to 1 inch.
AREAS OF PRODUCING TERRITORIES.
Allegany District . . . 81.3 Sq. M.
Bradford District . . . 132.6
Warren & Forest Districts . 35.4
Venango District . . . 65.4
Butler District . . . . 84.1
Beaver & Outlying Districts 20.2
Total 369.0 Sq. M.
Developed Oil Pools

thos
Pen
I
men
96,0
men
261,
the
wha
estir
proc
seen
the
mak
that
oil-s
the
gone
ing
a da

BY

T
adjo
kno
a w
was
brid
hav
thro
whi
dep
reta
mor
S

vania was commenced, natural gas has been obtained either in conjunction with oil or in wells which produced only a trace of oil. In most of the flowing oil-wells, the pressure which forces the oil up the well results from the gas contained in the oil-sand in the immediate vicinity of the well or at a considerable distance away. In the former case, gas is frequently mixed up with the oil as it intermittingly flows from the well-mouth, the gas coming from the well continuously between the oil-flows; while in the latter case, no perceptible quantity of gas is obtained from the well. I believe that, by special examination, all the oil coming from the Pennsylvania and New York wells may be proved to contain *some* gas.

The product of gas-wells has been utilized in various ways, particularly for light and fuel at the towns and villages in the immediate vicinity of the wells, and also to a limited extent for the manufacture of lampblack—sometimes called "diamond black"—by the deposition of the carbon resulting from the imperfect combustion of the gas. A comparatively small proportion of all the gas produced in the region, however, was ever made use of until within two years, when the introduction of gas into the industrial establishments—principally iron, steel, and glass-works—in the vicinity of Pittsburgh have made its use as a fuel an important consideration in the manufacturing industries of Western Pennsylvania.*

The geology of the oil-regions of Pennsylvania has been carefully studied during the past ten years by the geologists of the Pennsylvania survey, but more particularly by Mr. John F. Carll, who, since the commencement of the Survey in 1874, has been in charge of the special examination of that district. The detail geology of the region has been made public through numerous State reports,†

* It is estimated that at present there are being supplied with natural gas in the city of Pittsburgh alone, 1500 dwellings, 66 glass factories, 34 rolling mills, and 45 other industrial establishments, and that about 10,000 tons of coal are thereby displaced daily. The gas consumed in Pittsburgh, is used almost exclusively for fuel. The following figures, reported by T. P. Roberts, show the estimated value of coal supplanted by natural gas consumed in Pennsylvania, New York, Ohio, and West Virginia, in 1882, 1883, and 1884:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1882 | Pittsburgh region, | $ | 75,000. | Elsewhere, | $140,000. | Total, $ | 215,000. |
| 1883 | " | " | 200,000. | " | 275,000. | " | 475,000. |
| 1884 | " | " | 1,100,000. | " | 560,000. | " | 1,460,000. |

† See the following reports of the 2d Geol. Survey of Pa.: I 2, I 3, I 4, and J relating almost exclusively to the oil regions proper; L, for the Pittsburgh gas-well, and the use of gas in the iron manufacture (1876); Q, Q 2, Q 3, Q 4, for references to oil-rocks in Beaver, Lawrence, Mercer, Crawford, Erie, and S. Butler counties;

which relate principally to the consideration of geological problems affecting the occurrence of petroleum; they necessarily, however, refer indirectly to the geology of natural gas, although no great attention has been directed to the latter question until the past summer, when a special survey was commenced by Mr. Carll, for the State, of the geology of portions of Western Pennsylvania in the vicinity of the recently-discovered oil and gas-pools, more particularly the latter. Until this survey is finished and Mr. Carll's report is published, our knowledge of this interesting question must be more or less incomplete.

The extensive drilling which is now being done by manufacturers, gas companies, and property owners in all sections of Western Pennsylvania and contiguous areas in adjoining States, where it is thought natural gas may be obtained, has made the study of the geology of natural gas one of pressing importance as an aid to locate profitable wells.*

Much is being published as the result of interviews with practical gas-explorers and professional geologists on the subject; and, while I do not wish to anticipate the results of Mr. Carll's investigations, I desire to record a few general conclusions which have resulted from my personal field-observations extending over a period of ten years, and from numerous studies made in conjunction with Mr. Carll of the results of his oil-surveys, which have been more thorough, complete and valuable, than any which have been made relating to the geology of petroleum.

The general conditions upon which the occurrence of natural gas seems to depend, from a consideration of the facts at present at our command, are: (*a*) the porosity and homogeneousness of the sandstone which serves as a reservoir to hold the gas; (*b*) the extent to which the strata above or below the gas-sand are cracked; (*c*) the dip of the gas-sand and the position of the anticlines and synclines; (*d*) the relative proportion of water, oil, and gas contained in the gas-sand; and (*e*) the pressure under which the gas exists before being tapped by wells. Other conditions may still be discovered

K for the Dunkard creek oil-wells of Greene county; R, R 2, for descriptions of oil-rocks in McKean, Elk, and Forest counties; V, V 2, for notes on the oil-rocks of N. Butler, and Clarion counties; H 2 for oil-boring at Cherry Tree, Cambria county; G 5 for oil-boring in Wayne county.

* I believe it to be possible for an *experienced practical* geologist to define areas where it is impossible to obtain natural gas, and therefore, where it would be the height of folly to drill wells, and other areas where it is possible for natural gas to exist.

which will have as important a bearing upon the problem as these which I have stated.

The oil and gas-regions of Pennsylvania are one in a geological sense. The strata drilled through by the gas-wells in the vicinity of Pittsburgh (now considered the most important gas-district) are, in a general way, the same as the strata in the different parts of the Devonian and Carboniferous series pierced by the oil-wells at Smith's Ferry (30 miles north 60° west from Pittsburgh) and the Slippery Rock (34 miles north 20° west from Pittsburgh) districts, where, in both cases, heavy oil is obtained from the base of the Coal measures and amber oil from the Berea grit; in the Thorn Creek (25 miles north 5° east from Pittsburgh) and south end of the Clarion, Butler and Armstrong (28 miles north from Pittsburgh) districts, where oil is obtained from the Venango (Devonian) sands; and in the Pleasant Unity (30 miles south 65° east from Pittsburgh), Dunlap Creek (31 miles south 12° east from Pittsburgh), Whiteley Creek (45 miles south from Pittsburgh) and Dunkard Creek (48 miles south from Pittsburgh) districts, where oil is obtained from the Mahoning sandstone (Lower Barren Coal measures) and overlying strata. The discovery of oil at Mt. Nebo, about 8 miles northwest of Pittsburgh, and the several small oil-wells reported to have been obtained in close proximity to the Washington (Chartiers Creek) gas-wells, together with traces of oil found upon special examination in the gas from wells which are supposed to produce absolutely dry gas,* the existence of natural gas either in or near all the productive oil-pools under geological and physical conditions similar to those found to obtain in what are frequently spoken of as "natural gas-regions proper," are all sufficient reasons for considering the districts, containing wells which are supposed to produce either oil or gas exclusively, one geologically. This conclusion is an important one in the consideration of the geology of natural gas, and it is believed that it is fully borne out by the numerous columnar sections of strata in Western Pennsylvania which have been published by the Geological Survey.

The general structural geology of the oil- and gas-regions is comparatively simple. The rocks lie nearly horizontal, being thrown into broad and almost imperceptible rolls by southwest-dipping

* The gas obtained from the Carpenter well on the Daum farm, Westmoreland County, was supposed to be free from oil or water; when, however, the gas was confined under a pressure of 160 pounds to the square inch, water was precipitated. In the same way oil is found to exist in the gas from wells which are supposed to produce absolutely dry gas.

anticlines and synclines which are parallel, in a general way, to the escarpment of the Allegheny Mountains, and which produce gentle northwest and southeast dips from the crests of the anticlines down toward the centers of the synclines. An appreciation of the intensity of these dips may be had from the following figures: From the city of Bradford, in McKean County, immediately south of the Pennsylvania and New York State line, and about 72 miles, in an air-line, a little south of east of the city of Erie, the strata dip at an average rate of 14 feet per mile to Oil City, which is 64 miles south 55° west of Bradford. From Oil City to Pittsburgh, a distance of 70 miles in a direction south 12° west, the average rate of dip per mile is about 20 feet. From the city of Erie to Beaver, on the Ohio River, at the mouth of the Shenango River, the distance is about 100 miles in a direction south 7° west, and the average rate of the fall of the strata is 20 feet per mile. Although these are the general dips of the rocks, yet many very much greater local dips occur in the areas between the localities named. The maximum dip in the Bradford oil-region, which I determined from my surveys in 1879, was 69 feet per mile, and this for a distance of only 2½ miles. In the Venango oil-belt and southern end of the Butler oil-belt the dip of the oil-sands, as shown by Mr. Carll's survey, rarely exceeds 35 feet per mile. A dip in the strata at the rate of 75 to 100 feet per mile, for even very short distances, is the rarest occurrence.

Although the horizontal structure of the oil and gas-regions is comparatively simple, the columnar structure, as revealed both by the study of the outcropping rocks and the records and drillings of oil-wells, is not so easily understood, and in special areas is more or less complex. The rocks which have so far been found to produce natural gas are found in a vertical range of about 3000 feet of Carboniferous and Devonian strata, extending from the Mahoning sandstone at the base of the Lower Barren Coal measures, which is on an average about 500 feet below the Pittsburgh coal-bed, down to the Smethport oil-sand in McKean County, which is 360 feet below the great Bradford oil-sand of that region. The principal gas-horizons are (*a*), the probable representative of the Venango first oil-sand at Pittsburgh, which is from 1300 to 1850 feet below the Pittsburgh coal bed, and contained, as I believe, in the Catskill formation No. IX; (*b*), the Sheffield gas-sand, which appears to be the lowest oil- and gas-sand in Warren County—the horizon of this sand is about 800 feet above the bottom of the interval of 3000 feet—and (*c*), the Bradford oil-sand, which occurs 1775 feet below the base of the

Pottsville conglomerate, which is the lowest member of the Lower Productive Coal measures. The Sheffield and Bradford sands are undoubtedly of Chemung age.

While most of the largest gas-wells which have been drilled in Pennsylvania have obtained gas from these three horizons, yet gas in commercial quantities is not exclusively confined to them. Between the Mahoning sandstone as the top limit and the Smethport oil-sand as the bottom limit, about 10 (more or less) prominent sand-beds have been found which produce petroleum, and each one of these sand-beds has been found to contain gas in greater or less quantity, nor is it possible to say that the gas is confined exclusively to these definite sand-horizons, for sand-beds having only a local occurrence, but included within the rock interval of 3000 feet, may contain gas.*

The origin of natural gas has an important bearing upon its economic geology. Although it is believed that we are in possession of much data to throw some light upon this interesting question of cause, yet it is still shrouded in too much uncertainty to permit of complete explanation. It is necessary, however, that some statement should be made in regard to the origin of gas in order to thoroughly comprehend the conditions upon which its existence seems to depend. It would appear that the gas is closely related to petroleum,† and that

* Outside of Pennsylvania, in West Virginia, Ohio, and Kentucky natural gas is not confined to the Devonian formation, but has been obtained from strata as low in the geological column as the Lower Silurian limestone, although the most productive wells have obtained the gas from the Pennsylvania Devonian sands.

† According to Prof. S. P. Sadtler, the Pennsylvania and New York petroleum is a mixture of hydrocarbons which can be classed under the marsh-gas series (paraffines) having a general formula $C_nH_{2n+2}$, and the ethylene series (olefines) having a general formula, $C_nH_{2n}$. The composition of natural gas from different wells or from the same well at different times, is found to vary slightly; according to recent analyses made by Mr. S. A. Ford, the average composition of the gas in the vicinity of Pittsburgh is:

| | Per cent. |
|---|---|
| Carbonic acid, | .6 |
| Carbonic oxide, | .6 |
| Oxygen, | .8 |
| Olefiant gas, | 1.0 |
| Ethylic hydride, | 5.0 |
| Marsh gas, | 67.0 |
| Hydrogen, | 22.0 |
| Nitrogen, | 3.0 |
| | 100.0 |

100 liters weigh 64.8585 grams; 1000 cubic feet natural gas are equivalent in heating power to about 55 pounds of the average Pittsburgh bituminous coal.

their origin is due largely to the same cause—the decomposition of animal and vegetable life. It is believed that the gas is not indigenous to the sand-rock from which it is obtained, but comes from the decomposition of life-forms which were entrapped in underlying strata. If this be so, the amount of gas contained in any one sand depends, first, upon the extent to which the rocks are cracked between the horizons of such organic remains and the gas-sand reservoir in order to permit the gas to flow into the sand; and, second, upon the extent to which the rocks are cracked above the gas-sand, which would permit the gas to escape into the atmosphere and totally disappear.

That the absence of both petroleum and natural gas in our plicated strata east of the oil-regions is to be explained by the cracking of the rocks would seem to be evident, since the survey of the outcropping rocks and a study of the records of dry wells show that the oil- and gas-sands extend far beyond the limits of the area of the region in which any traces of oil or gas have ever been found. Even within the area where oil and gas-wells have been found the cracking or jointing of the rocks must have a potent influence upon the amount of oil or gas obtained in certain localities. From the surveys of Mr. A. W. Sheafer and myself in Elk County, it appears that the direction of certain streams is to be attributed to their flow along joints in the rocks, which have resulted from the contraction of the earth's crust during the process of secular cooling. I believe that this, in a measure, accounts for the occurrence of gas at certain points in western Elk County and its absence at other points, the gas being obtained where the rocks are not jointed, and not being found where they are jointed.

The first necessary condition for the presence of gas, however, is dependent upon the existence of a porous rock to serve as a reservoir to hold it. A number of wells have been drilled which have found gas, but, if the drillers' records are to be credited, have not pierced sand-beds; in these cases the gas has been unquestionably obtained from a crack in the strata which serves as a conduit to convey the gas from its sand-bed reservoir to the well. Although the dip of the gas-sand and position of the anticlines and synclines have an important bearing upon the occurrence of gas (in many cases this would seem to be the most important consideration), yet it is not believed that natural gas-wells can be located on what has been formulated as "the anticlinal theory," since all great gas-wells are not found along anticlinal axes, although some of the largest

and most important wells in Pennsylvania have been found in such positions. A great many wells have been drilled in synclines which have found gas. These two statements are of great importance, since a large amount of money is now being expended in drilling wells which have been located on the basis of the anticlinal theory, so-called. The following references to notable instances where gas has not been found on anticlines, and where it has been found in synclines, will serve as sufficient illustration:

Most of the saddles and basins in western Pennsylvania have a progressive dip along their axial line toward the southwest, and a well, drilled ½ mile to the northwest or southeast of a given point on the crest of an anticline, may encounter any given stratum at the same elevation as a well drilled immediately on the crest of the same anticline, at a distance southwest from the given point; the distances in each case being dependent upon the intensity of the dip in the three directions. The anticlinal along which the famous Murraysville gas-wells in Westmoreland County have been drilled is an instance. About 10 miles northeast of the village of Murraysville two large gas-wells have been obtained about 3 miles apart, northwest and southeast, one on Beaver Run, the other on Pine Run. The total dip of the Upper Freeport coal-bed from the Beaver Run well to the Pine Run well is 215 feet, or at the rate of 70 feet per mile toward the northwest. The former well is found in close proximity to the anticlinal axis along which the great Murraysville wells are obtained further to the southwest, while the latter well is near the synclinal axis. The extension of the general direction of this anticlinal line to the northeast of the Beaver Run well crosses the Kiskiminetas River near the mouth of Roaring Run, where a well was drilled, evidently on account of the existence of the anticline at that point, but no gas was found. The Apollo well, about 3 miles northeast of the Pine Run well, along a line parallel to the structural lines of the district, found no gas. In the case of the Roaring Run and Apollo wells, it may be possible that no porous stratum which could serve as a gas-reservoir was pierced by the drill; this, as already stated, is the first necessary condition of the existence of gas.

The Ridgway gas-well is located in a syncline, and not on a subordinate anticline, as has been suggested, but at a point where there is a certain regular dip of about 1° toward the west, on the side of the syncline. The Kane gas-wells, including the large one at Kane, which is now supplying the residents of the town with light and

fuel, and the famous Kane Geyser gas-well, are both in a syncline; the southeast dip in the one case, and the northwest dip in the other case, toward the center of the basin, being less than 50 feet per mile, and the southwest dip along the axis of the basin being from 15 to 25 feet per mile.

The great McMullen and Hallock gas-well,* commonly known as the "Mullen Snorter," is not in the vicinity of any anticline. The gas-sand at this well is nearly horizontal, having only a dip of about 11 feet per mile in a direction south 15° west.

The gas-wells found in the vicinity of the city of Erie are located in a region where no anticlines or synclines have been discovered. The dip of the rocks here is toward the southwest at the rate of about 20 feet per mile, from recent surveys, or, from the survey made nearly 50 years ago by the First Geological Survey, as pointed out by Professor Lesley, the average dip was estimated to be 14 feet per mile.

No anticlines exist in the vicinity of the Fredonia (N. Y.) wells, so far as the structure has been made out.

On the other hand, some of the largest gas-wells have been found on the crests of anticlinal axes; among them can be enumerated the Sheffield well, about 2½ miles east of Sheffield, which was drilled in September, 1875. This well still supplies the town of Sheffield with light and fuel and has proved one of the largest and most remarkable gas-wells ever drilled in Pennsylvania. The history of this well is interesting on account of the great pressure of the gas, which made the drilling difficult. A vein of salt water was passed through at a depth of 418 feet, the water from which was permitted to leak into the well; the gas-sand, which was 45 feet thick, was struck at a depth of 1350 feet. The great pressure under which the gas was confined in the sand-bed was relieved as the gas flowed into the well, and the sudden change of pressure caused heat to be absorbed from the water, which rapidly froze, until the well became almost entirely stopped up by the core of ice for a distance of nearly 200 feet above the gas-sand.

The Wilcox wells, 5 miles northeast of the village of Wilcox, in Elk County, are all located within ½ mile of the crest of the anticline which separates the Fifth from the Sixth bituminous coal-

* This well is located on the Loup farm in Olean township, Cattaraugus County, N. Y., and was drilled in the spring of 1877. It was one of the largest gas-producers ever obtained in the Bradford district. During the past three years it has produced but little gas, and during this time between two and three barrels of oil have been obtained from the well daily.

basin, the dips on either side of the axis of this anticline, toward the northeast and southwest, being at the rate of about 50 feet per mile. The dip of the rocks at the Sheffield gas-well is not quite so great as at the Wilcox wells.

The gas-wells in the vicinity of Marionville, Forest County; at Tarentum, in Allegheny County; at Murraysville, in Westmoreland County; and at Canonsburg, and Hickory, in Washington County, are all located in close proximity to anticlinal axes.

An interesting fact, connected with the dip of the rocks as independent of the position of the anticlines in influencing the presence of gas, is to be seen in the flooding by water of the gas-sand in the vicinity of Pittsburgh, as recently pointed out by Mr. Carll. A line showing the limit of the flooded rock at this point has been approximately located by Mr. Carll, and in the area included by it but little gas has been found, although the gas-sand has been pierced by the drill. The rapid diminution in the flow of the gas from the wells in the vicinity of East Liberty would seem to be due to the driving back of the gas by the flooding of the gas-sand with water.

The relative proportion of water, oil, and gas in a sand bed, and the pressure* under which the gas exists, have an important bearing upon its occurrence, when considered in conjunction with the dip of the sand and the position of anticlines. If nothing but gas existed in a given homogeneous sand-bed, having only the ordinary dip of the strata in the oil-region, from which the gas could not escape by cracks into overlying strata, and the quantity of confined gas being such that it should fill all portions of the rock with gas under a great pressure, it must be apparent, that, no matter where the gas-sand was pierced by a well, the same quantity of gas would be obtained, excepting so far as it might be influenced by the force of gravity. If petroleum, water, and gas should all exist in the same sand-bed, the pressure on each would necessarily be approximately† the same, if there was an open connection throughout the whole

* The pressure under which the gas flows from different wells varies greatly. In the Pittsburgh district it ranges on an average between 100 and 200 pounds per square inch. Mr. Carnegie reports that at their works, where the gas is used 9 miles from the well, the pressure was 75 pounds per square inch. When I visited the Bessemer Steel Co.'s works, at Homestead, on the 27th of last August, the recorded pressure was 60 pounds per square inch. The highest pressure I know of being measured was 750 pounds per square inch. I believe, however, I have seen the gas coming from wells under special conditions at even a greater pressure than this.

† The pressure at the bottom of a sheet of water or oil which nowhere, in the sand-bed, could be of any very considerable height, would be but slightly augmented by gravity.

extent of the rock in which they occurred; but the water would seek the lowest level of the sand-bed, the oil the next, and the gas would be found in the highest portions. The same condition of affairs would exist where either water or oil existed in the sand with the gas to the exclusion of the other.

A careful study of these facts makes it apparent that under special conditions the anticlinal theory alone may account for the existence of gas; but when, however, it is known that large gas-wells have been found in synclines, under conditions differing from those which obtain in the vicinity of gas-wells on anticlines, it is quite certain that the occurrence of natural gas in the Pennsylvania and New York regions cannot be explained but by a careful consideration of *all* the geological and physical conditions under which it is procured.

The facts relating to the geology of natural gas now in the possession of any one geologist are not sufficiently numerous or connected to permit the acceptance of any ultimate theory; and it is only possible for the present to deduce special geotectonic conditions under which natural gas has so far been exploited. Some of these conditions are so varying and apparently antagonistic that it is only possible to arrive at any general law, controlling the occurrence of natural gas, by a comparison of the individual facts obtained from innumerable well-drillings.

Mr. C. D. Angel, one of the most successful oil-operators in the early history of petroleum-mining, deduced a theory in 1867 accounting for the existence of oil in definite areas. This was known as the "belt-theory," and sought to maintain that oil would always be found along lines having a definite direction, irrespective of their length; and to this day many oil-wells are located on degree-lines upon the basis of the belt-theory. It has long been proved by the investigations of geologists and the results of practical drillers, that within individual oil-pools the most productive wells have been located along definite degree-lines; yet the belt-theory has long since been abandoned by the most intelligent operators, as being insufficient to account for the existence of petroleum under all conditions. The history of this theory will doubtless prove analogous to the history of the anticlinal theory as accounting for the existence of gas. Many gas-wells are now being located in Pennsylvania and West Virginia and Ohio on the basis of this theory, and in many cases the practical driller is rewarded by finding the object of his search; but it is quite certain that the theory as an ultimate means for the locating of gas-wells is quite insufficient, and will lead to failure in special cases.

## *TOPOGRAPHICAL MODELS: THEIR CONSTRUCTION AND USES.*

BY A. E. LEHMAN, PHILADELPHIA, PA.

A RECENT demand for some form of panoramic display of an important railway line, showing its branches, connections, and territory controlled by it, revealed to the writer the advantages of a topographical model or relief map for this purpose.

Hitherto, maps of this nature have been used chiefly for scientific and geographical purposes, and confined to a comparatively narrow field of service. They deserve to become more popular and to have their advantages better understood. Much has been written and accomplished in this direction by Prof. Lesley, Messrs. Harden, Moulten, de Mendonca Cortez, and others; but I believe their published descriptions of the methods employed in the construction of these models are confined to those used by themselves. It is the writer's aim to present in condensed form these various methods, and some suggestions of practical value as to the most economical course of procedure, as well as to mention some of the uses that may be made of the results obtained.

*Methods of Construction.*—Many different materials have been prepared and used in the preparation of relief maps, such as metal, clay, plaster, gypsum, wax, putty, card-board, papier-maché, wood, and compositions of various kinds, with results more or less successful: wood, however, in the writer's experience, has been found to be by far the most satisfactory, combining the advantages of stability, accuracy and ease of handling.

The following is a brief description of several of the methods used in constructing topographical models: When clay, wax, putty, compositions or materials of a plastic nature are used, the operator carries his work up from its base by means of measurements or by the eye, manipulating and shaping the material as best he can, according to such features of his subject as he wishes to delineate. This process requires remarkable skill, and given this, will probably fall short even then of an approximation to accuracy; lacking essential elements of detail all over the work and exactness, particularly in position and elevation of the most important points in the territory mapped.

When either of the above mentioned materials or compositions are used, metal or wooden pins are sometimes driven into the base or level datum plane of wood, the top of these pins giving the eleva-

tions required. As a guide to the proper position and elevation of the pins, the contour-line map (of course, in all cases a necessary prerequisite), of the same horizontal scale as that selected for the model, is carefully spread upon the base board. The pins are then driven firmly through the contour-lines into the board, the tops left standing at a sufficient distance from the latter, to represent the elevation of the several contour-lines, according to the vertical scale adopted for the model. The number and spacing of the pins driven are governed by the topographical features and detail desired. After the pins are all properly set, the material to be used to form the model is carefully worked into place over and thoroughly covering the pins, and is carved and shaped where necessary with suitable instruments; the pins, of course, guiding this operation. The surface of the model is then carefully smoothed off even with their tops before the material is allowed to harden or dry. Such a model may be satisfactory in appearance, but is not substantial, and must, of course, be carefully handled. It will not bear transportation freely, shrinks soon and cracks.

Numerous models have been constructed by the present Geological Survey of Pennsylvania. The methods used are well described by Mr. O. B. Harden, vol. x., p. 264, of the *Transactions* of the Institute. The tools required in this process are a scroll-saw with treadle for doing light ornamental work, a stylus, a light hammer, and a glue-pot. The materials are wood of a suitable kind sawed into thin boards of a thickness equal to the contour intervals of the map, small brads, glue, and red wax. The latter comes into use last of all, and is shaped over the surface of the wooden structure, filling up its re-entrant angles or steps, giving the surface a smooth appearance, and, in the hands of a skillful workman, permitting all small details of the subject to be accurately represented, without which the work would be flat and meaningless. The instruments used in moulding this wax covering are bone and ivory scrapers, such as are used by modelers in clay. The consistency of this wax is a very important matter. The ingredients and proportions are given in Mr. Harden's paper above cited, as follows: 16 parts of yellow beeswax, 8 parts of corn-starch, 1 part of Venetian red, 4 parts of Venice turpentine, and 1 part of sweet-oil. The wax must be soft, tough, plastic, very adhesive, and yet not too sticky to handle. The necessity for this material is, in my opinion, the weak point in this process of making relief maps. The models lack durability, owing to the non-adhesiveness, in many points, after a certain time, of this stratum of wax; as well as other disadvantages due to it that might be men-

tioned. Of course, there is a great deal I have not noticed in the work required in this process of construction; but the ground will be covered later on in this paper.

A method of making relief maps, which, I believe, has been patented in England, was invented by de Mendonca Cortez of Lisbon. It is certainly very ingenious, but, I think, far too tedious and expensive for American use. Here we have a variety of materials to choose from, but some of them would be exceedingly difficult and costly to use; particularly several kinds of metal which are suggested.

Whatever material is selected, be it wood, metal, or card-board, it is treated in this manner. As many copies of the map to be represented in relief are printed from the lithographic stone or engraved plate on sheets of paper or card-board, as there are height-indicating contour lines. These copies are then placed upon, and firmly fixed to, perfectly smooth and level plates of metal or other suitable material chosen for the purpose. The thickness of these plates is proportionate to the interval of distance between the contour lines of the original map, according to the vertical scale selected for the construction of the model. These several plates are then laid upon a suitable table and carefully cut out by means of a scroll-saw, knife or other means (if metal is used, the inventor does not say how this operation can be economically done), great care being taken to follow precisely the contour-line curves and to cut out a different height curve in proper ascending order in each plate. When this is done there will result, of course, a series of inner cuttings of different sizes and areas corresponding to the various contour-lines, and also a series of corresponding outer or bordering cuttings.

The inner cuttings are carefully placed one upon the other, in order of size and elevation, in accordance with the exact relative position of the contour-lines in the original map. They are then permanently fixed by means of glue, solder, nails, or otherwise, upon a perfectly level bed-plate or pedestal. By this means a perfectly proportioned *relievo* is obtained of the subject under treatment. This model or core is now marked with the requisite number of gauge-points, by means of which the map to be moulded in relief can be easily adjusted. The next proceeding is to cover this core with a sheet of moistened paper, of a sufficient thickness and size to cover fully the total area of the model. The thicker the paper can be the better and more substantial the final result. Upon the core thus composed and covered with the moistened paper, the outer or border cuttings are separately adjusted in their proper order, by

means of the gauge-points above mentioned. This is done in such a manner as to bring the outer or marginal cutting of that plate which has the largest aperture next (on top) to the base plate and adjoining and surrounding the bottom or largest plate of the core. The next marginal cutting (*i.e.*, the one having the next smaller aperture), is then placed upon the first and fitted to the size and contour of its corresponding plate of the inner cuttings, and so on in regular order up to the top and last marginal cutting, or plate having the smallest aperture, indicating the highest elevation of the ground and forming the top of the core. The cut-out plates being in this manner adjusted seriatim, two or more strictly vertical holes are drilled through them outside the limits of the map to facilitate succeeding adjustments.

The outside cuttings are now removed one by one and the moistened paper is withdrawn. There is now an exact model in relief or core and a complementary model in intaglio, matrix, or die, corresponding thereto. All this constitutes a pattern and machine suitable for moulding on paper of proper thickness a map in relief. The extent to which the map to be formed in relief will bear stretching and shaping, now being ascertained (if the operation has been a success), the paper is again placed in exact position upon the core by means of the gauge-points referred to, and moistened as often as may be required by brush, sponge, or other suitable means. The outer cuttings are then again laid in regular succession around their corresponding sections in the core, and are exactly adjusted by means of the holes bored in them; the paper of the map being pressed and drawn more or less, as may be required to conform to the desired shape. After the first marginal cutting is put into place, the paper is again moistened and another outer cutting is placed in superposition to the preceding one, and so on to the last one as before. Should the paper show any obstinacy to assuming the desired shape, it should be coaxed into form by gentle pressure and moisture. Finally, a level plate, as heavy as possible, is placed upon the top and the whole mass is subjected to suitable pressure.

The top plate and marginal cuttings are next carefully removed, one after the other, beginning at the top, and the map moulded in steps in relief is raised from the core, thoroughly dried and then stiffened with shellac or other suitable medium. It may then be mounted and braced in such a manner as to be properly protected.

I will here remark that after all this careful and tedious work, the result is in perishable and flimsy paper, in steps; the surface admitting of no embellishment in the form of geographical features,

such as streams, roads, towns, railroads, etc. Moreover, obstacles to practical use appear to be insuperable. However, the inventor continues and says that if a relief map with smooth surface and natural appearance is desired, the inner plates must be cut with a bevel along the hypsometrical curves and the marginal cuttings must be formed with overhanging bevels to correspond. In other words, the inner and outer cuttings must be cut with bevelled edges and at angles corresponding to the slopes shown on the original contoured map. These angles would be constantly varying, some being very acute, and the operation would be exceedingly difficult, if not really impracticable. The only advantage in a machine constructed on these principles—if it was possible to so construct it with reasonable economy—would be the facility with which duplicate maps could be moulded.

Mr. M. Moulton describes a method used by him during the year 1875–76, in the construction of a relief map of the State of New Hampshire, which is by far the best known to the writer. This method combines all the most desirable ways of working, and may be recommended as decidedly preferable to all others noticed in this paper. The map was made for Dr. Hitchcock, State Geologist, and when finished was about 16 feet in length, the highest elevation (Mt. Washington), being some 6½ inches above tide-water datum. The material used was basswood. From a copy of the topographical map of the State, made on tracing vellum, the sea-level line and the contour line next above it were traced through the cloth placed on a layer of basswood one-half inch thick and equal in size to the area of the map, by means of a suitable tracing point, pressed on hard. This produced two distinct impressions on the wood, which were then drawn over with colored pencils; blue for the outside and red for the inside line. The outer contour was cut around with a scroll saw, thus breaking off the wood outside of the sea-level line.

The pedestal or base-board on which the map was permanently to rest then received the first layer of wood, which was firmly secured by means of brads and glue. The next layer was then prepared for sawing, as in the first case, but the outside line of this layer was the first 500 feet contour, and the inside or red line was the next above. This also having been cut out with the saw, it was placed in superposition to the first layer and located by means of the red line before mentioned. These red lines served through the whole work as guides, by which each successive layer found its

proper position. The process of sawing out the contours in wood and building them up, was followed throughout the necessary number of layers, to attain the height of Mt. Washington. After three layers were firmly fixed in position, the steps or re-entrant angles thus formed at their edges were carefully shaved and carved off with keen-edged chisels and gouges to produce smooth slopes at angles corresponding to those shown on the original map. Each successive group of three or more layers was treated in the same manner.

When this had been done, the surface of the entire work was given a good finish by going over it with sand-paper, and coloring with a neutral tint. It was now to receive the geographical work. Water-courses, public highways, railroads, town and county lines were painted upon it in various colors and afterwards plainly lettered, including names of mountains. Previous to putting on all this detail, negative moulds were cast in plaster, from which positive casts were made for the use of schools and colleges throughout the State.

This model seems to have been made on the best principle known to the writer. No wax was used, and the work, when completed, was light and substantial. It might be suggested that to insure such work against warping and distortion, owing to drying and unequal shrinkage, the contour-layers of wood should be laid so that the grain of each should be at right angles to that of the next; and that the smoothing and dressing of the surface shall be done in such a manner as to allow the contour-lines of the map to be faintly seen over the entire surface, since, to be thoroughly practical and useful, relief maps should always show contour-lines on their slopes, yet not so distinctly as to destroy the effect of the geographical features represented.

It has been found that paper can be used in place of wood and treated in the manner just described. The absence of any perceptible grain and the facility with which it can be obtained of any required uniform thinness are two very important advantages possessed by paper. By slightly different handling it may be carved and moulded as easily as wood. It is very difficult to procure suitable wood of a uniform thickness less than $\frac{1}{8}''$ with planed surfaces. By band-sawing it has been produced as thin as $\frac{1}{16}''$. This, however, is a dimension that cannot always be guaranteed; and there are no means known by which these sawed surfaces can be reduced economically by planing.

The process of duplicating relief maps in plaster is described in

Vol. X., page 266, of the *Transactions*, and also in Prof. L. M. Haupt's admirable book, *The Topographer*.

*The Work of a Skilled Topographer Prerequisite.*—All the methods of work here imperfectly described, although requiring skill, are purely mechanical. As a preliminary to their employment, much the largest proportion of the whole labor required has to be done by the topographer. On him depends the success of the final result; his work is of a superior kind, requiring much more experience and skill. As the engraver on wood follows the design of the artist, so does the model-maker follow the contour-lines and other data supplied by the topographical engineer. Everything depends on the accuracy of these data.

For some purposes, the field-work, in the hands of an expert, may be hastily done and yet not involve errors of serious magnitude. The topographer must be able to analyze rapidly the characteristics of the district to be mapped, and above all, he must have a good memory and judgment respecting peculiar and important features observed. This is particularly necessary in regions that are wild and inaccessible, presenting serious obstacles to topographical work. Much more could be said on this part of the subject; but it would far exceed the proposed limits of this paper.

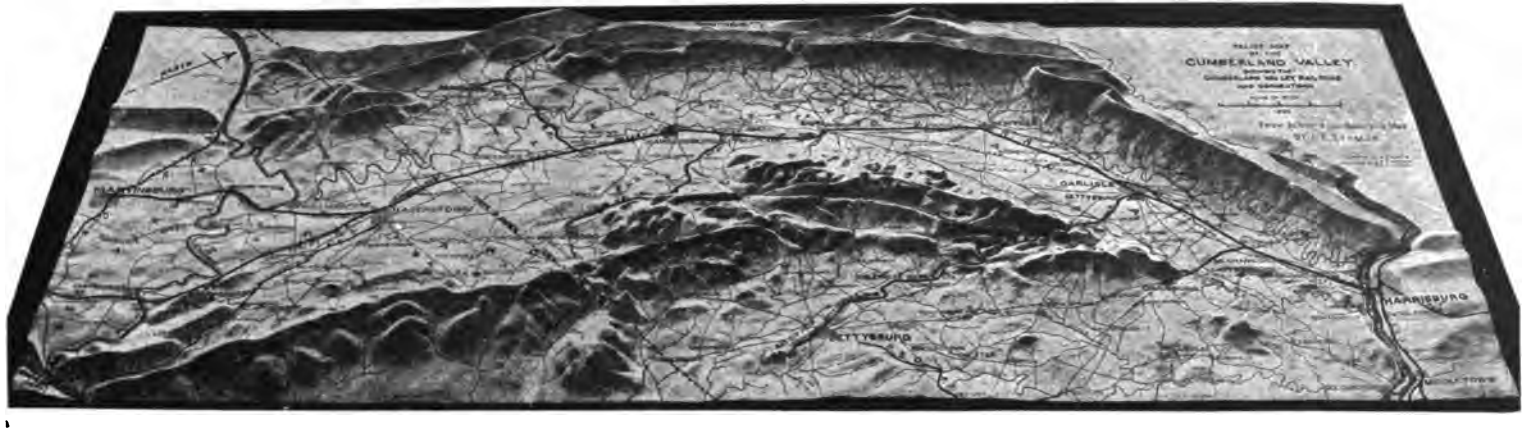
*Scales of Models.*—In few cases will the effect be satisfactory if the horizontal and vertical scales of a model are uniform. In the opinion of the writer, more or less exaggeration of the vertical scale is in most cases expedient, if not really necessary—the remark of an eminent geologist and topographer: "He that will distort or exaggerate the scale of anything will lie," to the contrary notwithstanding. A perfectly natural expression is of course desired; and to cause this the features of the topography should be distorted and exaggerated in vertical scale just enough to produce the same effect on the beholder or student of the district of country exhibited as his idea of it would be if he were on the real ground itself. Care should be taken, however, not to make the scales so disproportionate as to do violence to mental impressions. Often, indeed, prominent or important features, when they will bear it, may be still more effectively shown by additional exaggeration in the vertical scale. No distortion or exaggeration in the horizontal scale is ever required, except occasionally in the coloring of streams, railroads, towns, etc., to provide for photographing in certain positions. When views of the model from different positions are required, as these features do not appear in projection, they must receive proper treatment according to the rules

of perspective. As to the finish, the model should be neither useful at the cost of beauty nor ornamental at the expense of practical serviceableness.

*The Accompanying Illustration Described.*—The illustration accompanying this paper is a view of Cumberland Valley and the adjacent country, in Pennsylvania and Maryland, taken from a map in relief, constructed in the month of January of this year at Philadelphia, entirely from surveys and maps executed, and data furnished, by the writer. The mechanical and all other work pertaining to the model was performed by Mr. E. B. Harden, assisted by his brother, Mr. J. H. Harden, a pioneer in this art, who has done much to develop it. The finished model is in plaster, five feet long, two and one-half feet wide, cast in plaster from the wooden core surfaced with wax; it rests in a substantial frame of wood, braced and stayed by iron rods entering the plaster. As will be seen, the territory shown is nearly a rectangle in shape. The area covered is about 2752 square miles, comprising, in whole or in part, eight counties in Pennsylvania and four in Maryland. The horizontal scale of the model is 0.70 of an inch to the mile, with a vertical scale of 1600 feet to one inch. The relation of the two scales is 1 : 4⅔. The latter scale was made slightly too large, and a greater vertical exaggeration than was intended was the result. Two thousand feet to one inch would have proved more satisfactory. However, the work as a whole fairly met our expectations; and had it been possible for the photographer to do as well with his part of the task, the final effect as shown in the plate would be what we desired.

The original intention was to have photographic negatives made of the model, in sections as large as the camera would permit. A series of these were to have been taken from the original in different positions; the model afterwards to be laid aside for future use. Photographic prints of these negatives, in sections, were intended to be joined together, as Mr. Gutekunst has so frequently done with success, in large scenic views taken from nature. But this was found impracticable, because the model had to be placed at a rather flat angle to the camera, and the resulting perspective did not permit the printed sections to be joined without too great distortion in the picture. This principle in perspective had been overlooked.

The camera was next taxed to its fullest capacity to produce on a single negative a view as large as possible of the whole surface of the model. Subsequently a reduced copy was made, of which the view shown in the plate is a reproduction by the Ives process. The




View of a Model or Relief Map of the Cumberland Valley, Pa.

phototype process for illustrations of this kind may be strongly recommended, when the size of the picture desired does not exceed the possible limits of the camera, say: $20'' \times 20''$. The Ives process has in some respects advantages over all others, particularly in cost, but here the possible limits of size are $8'' \times 8''$. The inventor states that in time, as the process becomes more perfected, these limits may be increased. This is most desirable and would much enlarge its usefulness, which is now restricted to illustrations of book-size only.

*The Particular Section of Pennsylvania and Maryland Represented in the Illustration.*—Much might be said, did time and space permit, as to the geological and topographical features of this particular district of Pennsylvania. Some mention might be made of its historical associations also. These are innumerable, especially since the two great battles of Gettysburg and Antietam were fought on this ground during our civil war. But they are not pertinent to our subject, except so far as they serve to make our picture an object of more particular interest.

The most striking features of the picture are: first, in the foreground, the plain; next, in the middle distance, the South Mountains; then a section of what is called the Great Valley, this particular portion, extending from the Susquehanna to the Potomac rivers, being named the Cumberland Valley; and last, the North Mountain chain, with its crests forming a distinguishing feature and silhouette horizon in the distance.

The South Mountains in Pennsylvania are supposed to be the focussing-line of the picture, with the observer about 170 miles from and 50 miles above them, looking northwest. From this point of view, a magnificent outspread of country is commanded, tempting the beholder to examine it more closely in all its various details. It would be difficult to find a district of country where the close and remarkable relations existing everywhere between geology and topography are more clearly revealed, and the laws governing them are made more apparent to the student. A comprehensive rendering of this feature was one of the designs of the work.

The plain before mentioned, in the foreground, is elevated some 650 feet above sea-level, and is composed for the most part of Mesozoic sandstone and shales, with small patches of limestone to the south. Immense outbursts of syenitic trap occur and form in this section of the field, prominent elevations, of which the abrupt, cone-like forms of the Round Tops near Gettysburg, are fine examples. Both of

these were strategic points of the great battle, are now famous the world over, and are visited by many thousands of persons annually, attracted by the old fortifications, handsome memorial monuments, and numerous reminders of the conflict still carefully preserved.

Within the area covered by the Mesozoic sandstone are found numerous deposits of magnetic and specular iron-ore, many of which have been successfully mined. Particularly has this been true near Dillsburg, where the ores are found remarkably rich and abundant, and have for many years supplied a large output.

The trap highlands in the plain contrast greatly with the gentler undulations of the great valley beyond, over the mountains; here we find different geological conditions. On crossing the valley and North Mountains beyond, travelling west, say by the Monterey road (the line of Lee's mournful retreat from Gettysburg in 1863), the formations of the Paleozoic system are passed over seriatim from the limestone and slates of No. II, to the Chemung-Hamilton Upper Helderberg shales of No. VIII. This may be done with little deviation right or left; the regular order of the formations being but slightly disturbed by intervening areas of earlier ones repeating themselves. The first utterances of the formations to succeed those of the South Mountains are noticed immediately after leaving the outlying spurs and adjacent foot-hills of this range. Throughout the southeastern half of the valley, composed for the most part of limestone and calciferous slates (and elsewhere in these formations) are distributed numerous beds of limonite ores. Especially is this the case along the edge of the South Mountains. They are, from time to time, largely mined and go far toward making up the great mineral output and wealth of the whole region.

The Cumberland Valley shows itself in our view, somewhat in the form of a crescent, with a general direction northeast and southwest. This peculiar curve shape of the valley is a fact never before graphically shown, and quite surprised some of its oldest inhabitants, not a few of whom, even now, accept it with a certain degree of doubt.

The topography and geology of the South Mountain chain is, above all other sections of our territory, the most interesting. As will be seen, they form the southeastern wall of the great valley. As traced from the southern States, they continue with their characteristic ruggedness through North Carolina, the Virginias and Maryland, into Pennsylvania, only to be thwarted in their formation at Dillsburg, before quite touching the Susquehanna river, as can readily be illustrated by reference to the view.

Prof. Lesley, State Geologist of Pennsylvania, has referred to them, in some respects, "as a *terra incognita*." Since 1874, a careful topographical and geological survey of the Pennsylvania section of these mountains has been prosecuted with more or less diligence to the present time, under the auspices of the State Geological Survey. Until 1877, it was under the direction of Dr. Persifor Frazer; since that time it has been under my own personal supervision.

This range presents a most interesting study. Its closely assembled hills, wild broken gorges and stern central ridges (more than 2100 feet above the sea level), present a strong contrast to the long, regular, parallel ridges of the North Mountains, over beyond the valley, and forming its northwest wall. The former have all of the picturesque ruggedness with none of the monotony of the latter. They attract miners and geologists as well as artists and tourists, the latter by thousands every year.

Of its geological formation and structure much of scientific interest and importance could be said, did not time preclude. Dr. Persifor Frazer, during the progress of his work there, spoke of this region, in substance, in this language: "The great South Mountain chain is composed of essentially two great groups of rocks; the lower or northwest group, consisting of various modifications of quartz conglomerate in which quartzite occurs in various forms; and the upper or southeast group, which is felsitic in character, containing also large beds of hydro-mica and chlorite schists, intersected by veins of milky quartz. This may be regarded as provisional, simply, and subject to modification," according to results from subsequent examinations. It would be difficult as yet, to contradict these statements of Dr. Frazer, if they ever can be contradicted. My surveys have been exhaustive and are mapped in 10-foot contours, giving the location and dips of all rock-exposures, and should furnish reliable data for the construction of geological profiles and sections; but until all the evidence is summed up it would be premature to discuss the subject further.

By reference to the map, the location of Pine Grove may be found. Here occurs an isolated deposit of limestone cropping out at various points along Mountain Creek valley. In this locality are found the well-known Pine Grove limonite ores and mines, a property of great resources and value. These beds have been mined for more than one hundred years, and have yielded an immense supply of limonite ore; and yet the development may be said to have just begun. Here may be seen one of the largest open workings in the country,

exposing an unlimited quantity of ore, at Pine Grove, the terminus of the South Mountain Railroad. Much of the land in this range is valuable for agriculture. Some of the valleys, though narrow, are very fertile, and are changing from wild to pastoral scenes.

The railroad system of the district of country displayed in the accompanying view is worthy of brief mention. A total mileage of 500 miles is shown, probably involving a cost of at least $35,000,000. The Cumberland Valley Railroad, one of the oldest lines in the country, controls the traffic of the valley. This road is now well known for its superb alignment, easy grades and equipments. The Gettysburg and Harrisburg Railroad, starting at Carlisle, crosses the mountain by a most picturesque route to Gettysburg. Although an independent line, it practically connects this interesting neighborhood with the great Pennsylvania Railroad system, besides affording additional means of transportation for the minerals of the South Mountains.

*The Uses of Topographical Models.*—To a geological student, before going into practical work in the field, nothing is so comprehensive and graphic as this means of illustration, particularly when, after the geological formations are put in suitable colors upon the surface, the model is cut into sections and the strata and structural folds are shown in profile. Of the numerous models constructed under the direction of State Geologist Lesley for the Pennsylvania Geological Survey, and illustrative of many intricate geological and topographical problems, some have been treated thus, to better show complicated structure and demonstrate difficult problems. They bring into small compass and close relationship all evidence bearing on the subject, and show the formations as seen in place in the field.

Models are frequently of great advantage in suits at law, in settling mining claims and damages in dispute, when a resort to ordinary methods, maps, diagrams, etc., might fail.

For the graphic display of a railroad system and the territory controlled by it, nothing is better. To the President and Board of Directors of a railroad company, what could be more satisfactory? They are just beginning to remark on the advantages of this form of map. The management in considering the development of new territory would be greatly assisted by having it spread out in miniature, in this way. Furthermore, as railroad advertising displays, such models have no equal when photographed, lithographed and printed in color. The scheme of employing topographical models for this and other commercial purposes is, I may claim, an

original idea,* and is barely emerging from the domain of science where, heretofore, they seem to have been exclusively used, into the hands of new exploiters, who may expect to receive the condemnation of scientific enthusiasts for devoting such work to profane use. The scheme is intended especially as a substitute for the highly colored lithographic monstrosities displaying recent railroad systems and combinations. The means by which photographic views, of limited size, of models may be reproduced by lithographic process, in colors, on any scale, will readily suggest themselves to practical minds.

While models unquestionably offer the only correct way of representing in miniature a section of country, the expense, bulk or weight of any form of *fac simile* reproduction of the original will always stand opposed to their popular use excepting in special cases, as, for instance, for educational purposes. For such purposes they must be light, strong and of small cost. Various means and materials have been suggested, but paper in some form is perhaps the only material deserving consideration. The art is worth developing, and should be perfected; and some means should be found by which exact copies can be produced rapidly and economically. However, to best serve a popular demand, the photographic process can be used, and by phototypes, artotypes and lithographs (the latter for views on a large scale), models may be made practically useful, as illustrated by the accompanying example.

For educational purposes, much might be said recommendatory of these models. How much, for example, would the teaching of geography be simplified, could our educational authors and publishers be induced to leave worn paths, and, unfettered by tradition, develop a new system which, if carried out on a liberal scale, would work some improvement and lessen the tedium of present methods in geographical education, particularly to blind students? The use of topographical models would be found to contribute greatly to this end.

Geological and topographical models have also some artistic value; they are often framed and exhibited as ornaments. They may be said to be *alto relievo* work and to be to maps what statues are to figure-paintings.

Among notable models known to the writer, besides those before mentioned in this paper, and the interesting collection at the Smith-

* I have since learned that on one occasion this idea was suggested to a railroad official by Mr. Ashburner.

sonian Institution at Washington, are the following: Harden's model of Morrison's Cove, Pa., now at the Academy of Natural Sciences, Phila.;* the model of the Panther Creek coal basin, Pa., designed by Charles A. Ashburner, assistant geologist Pa. Geol. Survey; King's model of the United States, made by Mr. and Mrs. F. H. King, of Wisconsin (an unusually large example, constructed, I believe, to facilitate the study of physical geography); and Prof. Lesley's model of a large area of formation No. IV., in Pennsylvania, showing this formation cleared of all the upper rock-measures and exhibiting it in a continuous bed, with all its peculiar folds, and such portions as have been eroded above the present natural surface restored. This model is a most curious and interesting work, which exhibits some remarkable features of geological structure. Prof. Lesley has done much in a practical way to encourage and stimulate the construction of models for scientific purposes. As a proof of this, I refer to the large family of models that has grown under his able management of the Second Geological Survey of Pennsylvania, illustrative of the numerous and important geological and topographical problems met with during the progress of the survey. These models have all been made by Mr. E. B. Harden.

The King relief-map of the United States, above mentioned, probably shows the largest area ever attempted. The horizontal scale is 65 miles to one inch; the vertical scale, 5000 feet to one inch. The scales are as 1 to 68½. This model was made by casting a block of plaster in a wooden frame of the requisite size and depth and then reducing it by carving to the desired conformation, beginning at the highest points and working gradually down to sea level. This method has been used, experimentally, I believe, by others. Sliding or travelling vertical and horizontal scales, available at any point in the work, are necessary to secure correct elevations and positions of the different features. Mr. King is now said to be engaged on a model of the world, "attempting the configuration of both Continents and the ocean beds."

Wyeth's well-known model of Jerusalem and the surrounding country, at Ocean Grove, New Jersey, is a striking example on a large scale. It is about 50 feet in diameter. Here fine details are worked up with particular care, but the absence of scales and other necessary information makes a proper appreciation of the work quite difficult.

In a recent letter, Mr. Charles A. Ashburner kindly furnishes

* Topography and geology by Mr. R. H. Sanders; model by Mr. E. B. Harden.

me with a full description of his very interesting model of the Panther Creek coal basin, to which reference has been made.* This model is deposited at his office in Philadelphia. A duplicate, after having been exhibited at the New Orleans Exposition, was placed with the collection at the National Museum, at Washington.

The following is an abridged extract from Mr. Ashburner's letter:

"The sharp plications which exist in the Carboniferous strata of the anthracite region of Pennsylvania, which permit the outcropping of all the coal beds in the series along the ridges or mountains, limiting the coal basins, and the occurrence of the same coal beds in the centers of these basins at depths as great as 3500 feet in the vicinity of Pottsville, have made the study of the structural geology of the region, one encompassed with great difficulties. The necessity which exists of having some definite information in regard to the structural geology of the coal beds, before successful mining operations can be prosecuted, resulted in my designing, in 1880, a new method of representing on surface maps, the underground structure of the coal beds, from which could be ascertained (1) the location of the outcrops of the coal beds; (2) the position of the synclinial and anticlinal axes; (3) their depths in special coal beds below the surface of the ground; and (4) the dip of the beds from the crest of the anticlinal to the bottom of the synclinal. This was accomplished by contour curve-lines drawn along the floor of the coal beds (1) from elevations determined in the areas where these coal beds were mined; (2) from exploring the shafts and drill-holes, and surface exposures, in areas where no extensive mining had been done; and (3) in areas where no underground exploration had been made, by deducing the position of the contours along the floors of the coal beds, from surface exposures and an extension of the structure from areas where actual exploration or exploitation had been done.

"After the construction of the contours in exploited and explored areas, one of the most important aids to the determination of the geological structure of the coal beds in areas where surface exposures could not be obtained, has been found to be the construction of a model (vertical and horizontal scales being the same) which should show the shape of the floor of the bed. The first area which was so mapped in the region by the anthracite survey was that of the Panther Creek coal basin, lying between Mauch Chunk, in Carbon County, and Tamaqua, in Schuylkill County.

* Made by Mr. E. B. Harden, assisted by Mr. O. B. Harden. This work required and exhibits much dexterity in its construction.

"This is one of the most highly complicated coal basins in the region; and many of the difficulties were not understood until a model was made of the floor of the Mammoth coal bed, which is not only the most important coal bed in this special basin, but the thickest and most valuable bed which is mined throughout the entire region.

"A map was first made on a scale of 800 feet to one inch, upon which contour-curve lines were constructed along the floor of the Mammoth coal bed, 50 feet vertically apart, in the exploited and explored areas. In the areas included between the two classes, theoretical contour-curve lines were drawn on the map, which are consistent with the dip of the exposed strata in each special area."

From this map the model was made in wood and wax, as previously described.

"Thus the final model not only formed a graphical representation of the shape of the floor of the coal bed, but proved a great aid in the definition of the geological structure.

"The use of this system of modeling as an aid to the study of the structure of the strata in a highly plicated region, such as the anthracite, I believe is almost indispensable, in order to insure the best geological deductions as an aid to practical mining.

"The horizontal area of the surface of this model included between the outcrop lines of the Mammoth coal bed, is equivalent to an area of $10\frac{7}{10}$ square miles in the Panther Creek Valley, and if all the convolutions of the floor of the Mammoth coal bed, represented in the model, should be flattened out, the horizontal area would represent on the ground $16\frac{7}{10}$ square miles. The practical application of this model for the deduction of many conclusions affecting the amount of coal contained in this coal basin and the proper methods to pursue in its ultimate mining, has been very great.

"This was the first time that such an underground model was constructed in this way, and for the purposes for which the Panther Creek model was designed by myself; it has attracted the attention of many of the mining engineers of the anthracite fields, and of eminent professional geologists."

The above statement certainly contains strong and satisfactory evidence of the practical value and advantage of this manner of illustration.

In conclusion, I will say that all the information within my reach on this interesting and important subject has been presented, with the hope that its further study may thereby be promoted. I

have endeavored to put this information in such form as to answer the fit demands of those wishing to advance the art of making and using topographical models.

---

## *BASIC REFRACTORY MATERIALS.*

BY T. EGLESTON, PH.D., NEW YORK CITY.

THE necessity of using a refractory material capable of much greater resistance to chemical action and having a far higher melting-point than those which contain silica, which melt and sweat off in the furnace even when not exposed to bases forming with silica more or less fusible compounds, has led to a careful practical study of all those materials which contain very refractory bases. The results of these researches, extending over several years, and made on a very large scale in many of the largest works in Europe, are of the highest interest, not only considered as a step in the progress of the study of the materials themselves, but in the application of refractory materials to metallurgical uses in general. The result of the experience of the last seven years with these basic materials, as in general with all such substances, is that natural products cannot be used as such. They are either too uncertain in their quality, contain substances which may in certain cases be very injurious, or, when in a condition in which they might be used, are so rare as to become practically unavailable for employment on a large scale. The materials that may be used are therefore not only limited in number, but they must be prepared artificially. When the use of basic artificial material is further extended, no doubt the number of these substances will not only be greatly increased, but the methods of preparation will be both perfected and cheapened to such an extent as to permit their application in processes for which they have hitherto proved too expensive. The quantity of refractory materials required for making ingots will be from 130 to 150 lbs. per ton, or between 6 and 8 per cent. of the metal produced. In an establishment producing 2000 to 3000 tons of steel per week, considerable space is required to handle the basic materials properly.

It is proposed in this paper to briefly discuss these basic materials and their application in the only two metallurgical processes where they have as yet been applied. These are the basic Bessemer and the basic open-hearth process, known as the Thomas-Gilchrist processes.

The materials that may be used are bauxite, chrome-iron, lime, dolomite, magnesite,—when it does not contain too much silica, which is seldom—or artificially prepared magnesia.

Bauxite is a comparatively rare mineral, found only in a few places, and, in most localities, of uncertain composition. A little silica or an excess of oxide of iron makes it fusible, and therefore not suitable. When pure, and burned, it is not plastic, and must be mixed with some aluminous material to make it so. It cannot, therefore, be used on a very large scale. It has only been successfully applied to the separation of the basic and acid materials in the basic open-hearth process.

Chrome-iron is exceedingly refractory, but cannot be used in very large masses. It is used in large pieces for lining the cupolas for burning dolomite. It is generally crushed and mixed with tar to form the junction between the basic and silicious material in the open-hearth furnaces. This, magnesite and bauxite are almost the only materials that can be used for this purpose.*

Lime and dolomite, used alone or together, or magnesia extracted from dolomite by some chemical process, seem to be the only materials that are practicably available for basic refractory linings.

Dolomite is not absolutely essential, as limestones will answer perfectly well, provided they contain a small proportion of clay. If the limestone is perfectly pure it is difficult to burn, while if it is too impure it is very likely to frit or to fuse. It has been found by experience that eight per cent. of these foreign matters does not affect it seriously, but of this percentage there should be some alumina, and as little silica as possible. The presence of iron is also to be avoided.

Dolomite may be used either by itself or simply for the magnesia which is extracted from it, as is the case in a number of the continental works. It should not be too pure, but it is impossible to say just how much or how little foreign matter it should contain to be of the greatest utility. It may be said, however, that whether the dolomite is to be used by itself, or the magnesia is to be extracted from it, the higher its contents in magnesia, the better. The dolomite contains generally 2 to 3 per cent. of silica, 2 to 3 per cent. of iron, and 30 per cent. of carbonate of magnesia.

Burnt lime has been, and still is, used for the bricks, but it is expensive when burned at the same high temperature as dolomite; and there is very little if any advantage in using it to compensate for the difficulty of keeping it, which has proved a serious objection.

* "Basic Open-Hearth Process," *School of Mines Quarterly*, October, 1885.

Because of the difficulty of finding a limestone that will answer all conditions, dolomite is almost universally used; for while the presence of magnesia is not indispensable, the combination of constituents that seem to answer the purpose best is usually found associated with it. Its use was almost universal, and seemed for a long time to be destined to become entirely so. It now seems likely, however, to be supplanted in the near future by artificially prepared magnesia.

The carbonate of magnesia, as it comes from only three or four localities, has been found too costly, and not sufficiently advantageous to be used to any great extent. If it could be obtained pure and free from silica it would, when calcined, be the most useful material for the purpose yet tried.*

It has been proposed, in addition to the foregoing substances, to use ores of iron; but the difficulty of forming any mass with such material that would not be fusible and that would hold, has prevented its use. The danger of portions of a ferruginous lining becoming detached and falling into the melted steel has also aided in preventing its adoption.†

If natural material found in a given neighborhood does not possess the precise composition required, the amount of the constituents wanting may be added to it. This necessitates the complete pulverization and mixing of the materials, making them up into bricks, and then burning and regrinding them—an expensive operation which is not practicable to any great extent. Whatever the material may be, it must be calcined so long and at such a high temperature that it will not afterward either slack, except upon long exposure, or contract at any heat to which it may be put in the converter. The calcination must be done with care, since it is desirable that the pieces burned should not split under the influence of heat, and that there should not be a large amount of fine material produced. This consideration is so important and affects the cost so unfavorably that the manufacture of bricks made of such artificial mixtures has generally been avoided, except where it is indispensable.

Magnesia prepared artificially was used at Hörde for several years, and seemed at one time likely to take the place of much of the acid material now used. But after long trial it was found to be too

* "Basic Open-Hearth Process," *School of Mines Quarterly*, October, 1885.

† It would seem as though a water-jacketed converter, which would be not basic but neutral, ought to answer; but the danger of using it, or the enormous supply of water required for a large output, seems to have prevented any one from adopting it.

expensive to compete with the manufacture of the tar-bricks, and its use in the converter was abandoned. They are now, however, making a series of experiments in the hope of being able to use the magnesia bricks in furnaces where very high temperatures are required—and with every prospect of success.

When the processes by which magnesia is made can be cheapened, as there seems every probability of doing, it will be one of the best of all the materials used. A description of the process by which it was manufactured at Hörde will not be out of place, although it has been abandoned in those works, because it was of itself interesting, and some application of it which will cheapen it, may possibly be made again. I have given a short description of the process of making magnesia from sea-water which is now being experimented upon on a large scale, for making bricks used in the basic works, and will probably prove to be a very useful invention.

At Hörde, for several years, magnesia extracted from dolomite was used with great success. It was made on a large scale and had the advantage of being a perfectly homogeneous material, almost pure, which could be stored much longer than the dolomite bricks. Two processes were used, equally simple, and giving equally good results. The first was invented by Dr. Scheibler, of Berlin, the second by P. Closson, of Paris.*

Dr. Scheibler's process consists in burning the dolomite to drive off the carbonic acid, and then making a thick milk of it with water. Into this is poured a solution of molasses and water containing 10 to 15 per cent. by volume of molasses. The mixture is carefully stirred with a mechanical stirrer. In a few moments saccharate of lime is formed, which remains in solution while the magnesia is precipitated. The reaction which takes place is very simple:

$$\text{Molasses} + \text{CaOMgO} = \text{saccharate of lime} + \text{MgO}.$$

The milky material is put through a filter-press. The magnesia remains behind and the saccharate of lime passes through. This is then treated with carbonic acid, which precipitates the lime as carbonate:

$$\text{Saccharate of lime} + CO^2 = \text{molasses} + CaO,CO^2;$$

* The description of the two processes for making magnesia was written at Hörde, August 21st, 1882, where I saw the Closson process, which was then being worked there on a large scale. The details of both processes which I could not see, were given to me by Mr J. Massenez, the director of the works. These processes have since been described by Dr. Wedding in *Die Darstellung des schmiedbaren Eisens*, Braunschweig, 1884, p. 43.

the whole is put through a filter-press; the lime after washing is used or thrown away, and the molasses is used over again. The composition of the magnesia so obtained was:

| | |
|---|---|
| Silica, iron oxide and alumina, | 1.47 per cent. |
| Lime, | 2.18 " |
| Magnesia, | 95.99 " |
| | 99.64 |

The loss in molasses was found to be from 5 to 10 per cent. This loss was too large for economical manufacture, though the qualities of the bricks were unexceptionable.

This process was replaced by the Closson process, based on the use of magnesium chloride, which is one of the by-products of the manufacture carried on at Stassfurt, and is there thrown away in very large quantities as useless. The reactions which take place are quite as simple as in the former method, and are expressed by the formula:

$$MgCl^2 + CaO,MgO = CaCl^2 + 2MgO.$$

To carry out these reactions a sufficient quantity of the Stassfurt magnesium chloride is added to dolomite which has been burned and made into a milk, both being mixed together with sufficient water. The tub in which this is done has a series of arms fixed on its side and others revolving on an upright axis. The reaction takes place rapidly. When it is quite complete the tub is tapped from the bottom and its contents are run through an ordinary sugar filter-press from .50$^m$ to .60$^m$ square, and pressed. The chloride of lime runs out and leaves the pure hydrate of magnesia in the filter. This is carefully washed with water and leaves the pure hydrate of magnesia in the press, while the chloride of lime is collected in a basin. To utilize this material it is carried to a receptacle like that in which the blast-furnace gases are washed, except that it has revolving wheels to stir the chloride, making a thorough mixture of the gases and liquid. Two of these receptacles are placed together back to back. Above is a valve-box with a valve which, when one side is done, can be reversed so as to send the gases to the other side, and thus keep up a continuous working. Into this box a quantity of freshly burned dolomite is put, together with the chloride of lime. The blast-furnace gases passing through precipitate the lime, have their carbonic acid or a part of it removed, and are thus rendered more combustible. They deposit, besides, a considerable quantity of the solid materials carried off mechanically with them and are

thus made cleaner. Magnesium chloride is re-formed which remains in solution. The reaction is shown by the following formula:

$$CaCl^2 + MgO,CaO + 2CO^2 = MgCl^2 + 2CaO,CO^2.$$

The liquor drawn off is filtered, the mud and the carbonate of lime are thrown away, and the chloride of magnesium is used over again. There is but a small loss, not more than 5 to 6 per cent., of chloride of magnesium. The magnesia obtained by this method is made into bricks and burned. It is then reduced to powder, mixed with a little water, and formed into bricks of any shape in a hydraulic press, which, with four men, makes 4000 small bricks a day, two at a time. The same press is used for the tar-bricks. After a few hours' standing in a dry place these bricks are quite hard. The filter-press makes one filtering and washing in 45 minutes. It contains 25 moulds about 0.02 thick. The two presses make about 230 kilos at a time, or a ton of magnesia per day in a single press. To produce the ton of magnesia, 1250 kilos of dolomite and 8750 of the magnesium chloride are required. The total cost is about 4 marks per ton. The analysis of the magnesia produced is:

| | |
|---|---|
| Silica, iron oxide, alumina, | 1.05 per cent. |
| Lime, | 1.94 " |
| Magnesia, | 96.90 " |
| | 99.89 |

The difference between the products of the two processes is hardly appreciable, and they are nearly alike in cost. Closson's process is not applicable except in the vicinity of works like those of Stassfurt. Scheibler's process can be used wherever molasses can be had at a moderate price.

It is now proposed to make the magnesia out of sea-water which contains about four pounds as chloride or sulphate in a cubic yard of water. This is done on a large scale on the Mediterranean coast of France, at Aigues Mortes, with milk of lime, the reactions being the same as in the Closson process. The sea-water is pumped into a tank made of masonry, and milk of lime in the proportion of 1.5 per cent. of lime for every per cent. of magnesia is pumped into it at the same time. From here it flows into two similar tanks, where the two liquids are mixed mechanically by means of stirrers run by power, to be then filtered into shallow excavations about 1000 feet long and 16 feet wide, on the bottom of which there is a bed of clean beach-

sand. When enough has collected, the stream is turned off and the precipitate is allowed to dry in the sun. This takes twenty to thirty days, and can only be done in the summer. In the winter it must be artificially dried, which can easily be accomplished. The dried material is calcined at white-heat, ground, and made into bricks, as at Hörde. If this process proves a commercial success it will replace, to a great extent, and perhaps altogether, the manufacture of dolomite bricks.

The use of magnesia has the great advantages of simplicity of operation and uniformity of product. The amount of magnesia necessary for a ton of steel is only one-third as much as is required of dolomite, while it lasts much longer in the converter, when properly made by hydraulic machinery. It can be made into bricks by mixing with water only; the process of manufacture is therefore much more simple than that of the dolomite. Moreover, the magnesia bricks can be kept a much longer time without danger than any others. They also resist pressure at least as well as the others. Notwithstanding all these advantages it has been found, up to the present time, that the manufacture which involves the comprehension of nice chemical reactions cannot be carried on by ordinary workmen in competition with the tar-bricks, and the processes of Closson and Scheibler have been abandoned for the present at Hörde. The sea-water process is still in the trial-stage. The use of magnesia as a refractory material has, however, too many advantages to remain long dormant.

Whatever natural substances are used for the manufacture of basic refractory materials must be calcined at a very high temperature, in order to make it certain that no subsequent change of form from contraction will take place. There are two general methods of such calcination. The first, which is very generally employed, is carried out in the shaft furnace; the second, in some kind of gas-furnace, the object in this case being not only to have a very high temperature, but also to avoid the introduction of silica or other impurities which come from the ashes of the coke.

It has been found expedient, in most of the works in England, to burn in cupolas, raising the temperature to a white heat, and then selecting from the product those pieces only which are of a certain color, rejecting every piece not sufficiently burned, or which shows any kind of agglomeration, and breaking off any adhering siliceous material formed by the ashes of the fuel. It has been found possible in England to operate this method successfully, and produce an excellent brick.

The chief objections to the cupola are, that, as the temperature cannot be regulated, there is danger that the dolomite will not be heated sufficiently to prevent further shrinkage in the converter; that it makes a considerable quantity of fine dust by abrasion; and that the ash of the fuel is likely to form more or less fusible siliceous attachments to the pieces. As it is quite impossible to always have a perfectly pure coal, the material will frit and form engorgements in the furnace which after a time force it out of blast. This is partly remedied by having the center on wheels, as at the Northeastern works.

The system of continuous regenerative calcining-furnaces is used on the continent. These furnaces use less fuel than the cupola, and are free from the objections just named; so that, by their use, little of the material is damaged. It must be understood that in both cases the temperature must be very high, for, should the material be submitted to a higher temperature in the converter than it has already endured in the calcining-furnace, it would undergo a still further contraction.

The disadvantage of the cupola or shaft-furnace—namely, its liability to engorgement, although the lining is always basic, and the consequent necessity of putting out the furnace to remove the obstructions—has been already mentioned. The cupola requires also the constant work of a number of men, not only to charge but to discharge it; and it must be worked with long iron rods, in order to make the material come down quickly enough.

In the continuous furnace there is no difficulty of this kind. The hearths only of the furnaces are made of basic material, the sides and roof being siliceous. No inconvenience results from this, since the material to be calcined does not touch the sides of the furnace at all. In such a furnace as the Mendheim, Fig. 1, which is used at Hörde, there is no loss of time and material, and comparatively little fuel is burned in order to produce the temperature required.

The arrangements for receiving and calcining the dolomite are different in different works. In almost every instance the stone is sent to the works in cars, a large supply being kept on hand, and is burned as required for use. Occasionally it is purchased already calcined, in which case the calcination should have been done at a very high temperature, and the material should be stored in a dry place, and used as quickly as possible. There are too many uncertainties connected with this method of working to make it generally desirable, and it is practiced in only a few places.

At the Northeastern works the dolomite is brought in at one end of the works and stored in bins. Next to them are three cupolas for burning it. These are lined with basic bricks, as no other material would stand the contact with the dolomite at the high heat employed. The dolomite is mixed with coke and burned for nine hours. It comes out at a white heat, is shrunken to half its previous dimensions, and has lost half its weight.

At the Rhine steel works the cupola is about 10 meters high, including the chimney, and 2.5 meters in diameter on the outside. It is blown with two tuyères, and consumes about 65 per cent. of coke which has 8 per cent. of ash. The calcined material is drawn from four draw-holes at the bottom about 0.65$^{m}$ square.

At the Northeastern works the central section of the cupolas is supported on wheels so that it can be rolled out to be re-lined. It is about eight feet high. The bottom and top remain permanently fixed. The space between the two, above and below, is rammed with slurry.* One lift serves for bringing up the charges for the three cupolas, which are not all worked at one time. Two barrows of coke are used for burning, seven of dolomite, in pieces about the size of the fist. The bottom of the furnace is closed by a door. When this is opened the charge does not always fall by itself, but requires raking with long iron rods from below in order to detach it. Occasionally the charge becomes agglomerated, and can only be detached with great difficulty. The material, raked out about once in two hours, falls, mostly at a white heat, about seven feet upon the iron floor below. The dolomite contains some iron, and some of the pieces are fused or partly so. These are carefully picked out and thrown away. Those which are insufficiently burned are put back into the cupola. The pieces are shrunk to a very irregular form. They are spread out on the iron floor to cool, and, when picked over, are charged in a lift to be carried to the grinding apparatus.

The lining of the movable body lasts about 40 turns. It has lasted as long as 60. This depends partly on the way the furnace is worked, and to some extent on the quality of the dolomite burned. The basic lining is abraded, both by the descent of the charge and by the action of the tools, and when too much worn, the central part is detached, rolled out, and re-lined. The amount of fuel required to burn the dolomite is from 1300 to 1600 lbs. for every ton of shrunk dolomite produced.

* "Slurry" is the mixture of tar and shrunk dolomite, which is liquid when hot. When the mixture is only sticky while hot, it is called "mixture" or "ramming."

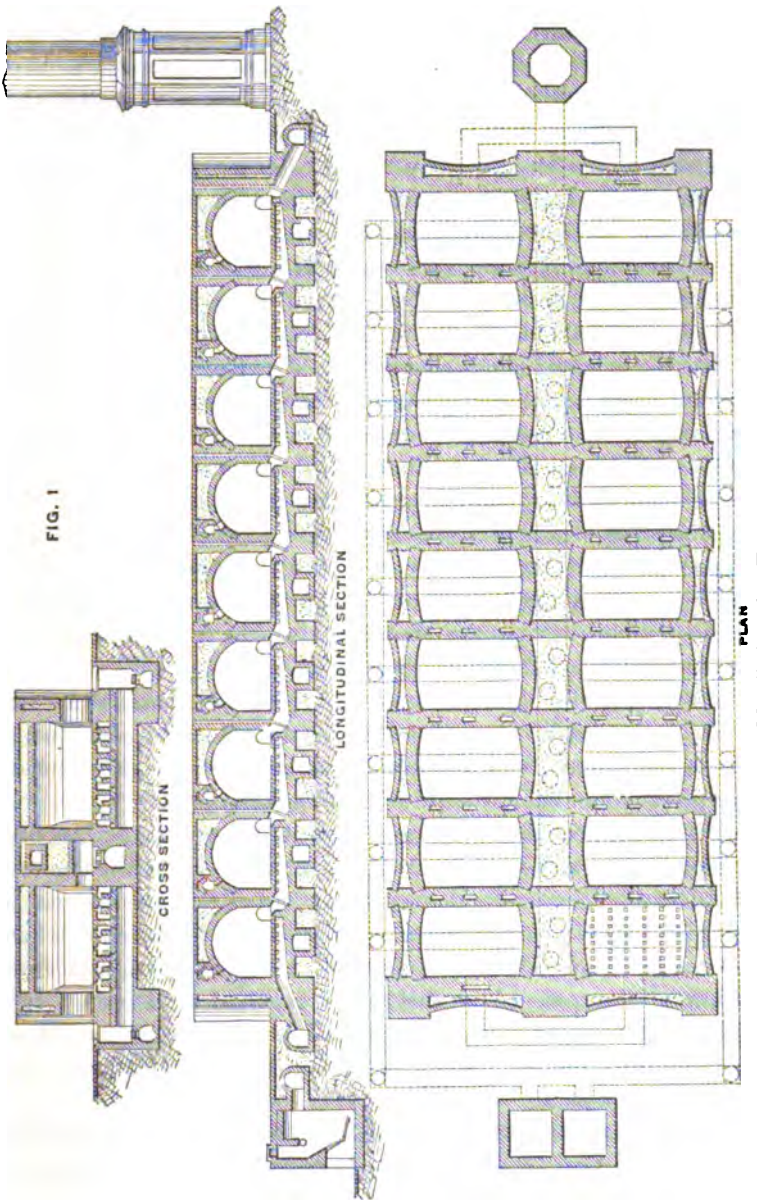
At the South Staffordshire works the dolomite for the bricks is for the most part purchased already burned. The cupolas are used mostly for burning the old bricks. It has been found worth while here to reburn them all before crushing, and not to use them directly without reburning, as is done in most of the other works in England and in Germany. The brick and the dolomite are ground in a Chilian mill which is attended by one man.

At the Alexandrowsky works in St. Petersburg,* where the open-hearth basic process is used, the cupola furnaces required to be repaired every two weeks when they were lined with basic bricks, and for these blocks of chrome-iron-ore have been substituted. Each of the four furnaces has an iron mantle, and is $3.5^{m}$ high and $1.75^{m}$ in diameter. Each has seven poke holes at different levels to work the material in the furnace from the outside. The lining is made $0.15^{m}$ thick, of blocks of ore laid up with a mortar made of two parts of fine ore and one of lime. Such a lining lasts three months of constant use. As it does not hold very fast, great care must be exercised in working scaffolds or obstructions in the furnace from the outside not to dislodge the lining. When such a furnace is to be put into blast, it is filled with wood to the height of 1.20, over which $0.60^{m}$ of refuse coke from the producers is put, and then 560 kilograms of dolomite and 260 to 300 of coke. The whole is then lighted. The furnace is drawn every twelve hours, and 3200 kilograms of shrunk dolomite, which is about 51 per cent. of the charge, is removed. It requires 1200 kilograms of coke to produce one ton of shrunk dolomite. The burned dolomite is cooled and broken by hand to pieces of about the size of the fist, and then sorted into three classes. The first is well burned, of high gravity and very tough; the third is porous and light, and constitutes about 25 per cent. of the entire product; the second is between the other two in quality. The first and second are broken fine and mixed with tar, and are used for making slurry. The first only is used, mixed with burned dolomite, in making the hearth of the furnace. The third is not mixed with tar, and is only serviceable in making the repairs which are necessary after every casting.

At Hörde most of the dolomite is burned in a Mendheim ring-furnace, Fig. 1, so arranged that the heat may, by opening or closing a valve, pass in or out of a compartment. The furnace here had sixteen chambers. Fourteen is probably the least that it would be profitable to construct. The bottoms of the compartments are made

* *Stahl und Eisen*, vol. ii., p. 603.

of the dolomite bricks, and the sides of ordinary fire-brick. The dolomite is piled in pieces four to five tin es the size of the fist on




Mendheim Ring-Furnace.

the floor, so as to touch neither the sides nor the roof, and heated gradually up to a white heat, and is gradually cooled, the dolomite

itself being used to store the heat necessary to bring the air up to a proper temperature for the combustion of the gases. The furnace is not opened until all the material is cool enough to be handled. The fuel is poor coal, burned in a producer. This furnace has the advantage of not only being a continuous one, but it may also be kept constantly at work, if desired, at other things as well as the calcination of the dolomite, for, as the temperatures are under control, and the chambers not very large, it may be used for treating a number of substances at a time. The repairs to the furnace are small, and the amount of fuel and labor required are not large. Both the cupola and the Mendheim furnaces are in use at Hörde. The disadvantages of the former have been found to be that it gives too much dust by the reducing of the dolomite by abrasion in passing through the furnace, and that the material is not evenly burned. The advantages of the Mendheim furnace are so great that the cupolas are used only to supplement it, or when this furnace is occupied with other work.

When the dolomite is properly calcined, the surfaces of the pieces are extremely uneven, and the pieces very irregular in shape. The surface is always more or less brilliant and generally concave. The hardness has also been greatly increased. It must be carefully inspected, and any pieces that are fritted or show any signs of fusion must be rejected. From the Mendheim furnace this can be done as each piece is being taken from the furnace.

From the cupola, on the other hand, the whole charge drawn at any one time must be spread out on the iron floor to cool, and is then inspected, but the inspection is never as thorough as where every piece is handled, as it is in the Mendheim furnace.

After inspection the pieces are ready to be ground. The first breaking is done either by hand or in a Blake's crusher. The machine does the best and quickest work. After this the material is carried in some kind of an elevator or conveyor to the mills where it is crushed to pieces of about $0.004^m$ to $0.005^m$ cube, and from which it is delivered only as fast as it is required to be used. It is usually made into two sizes, coarse and fine, which are mixed together in different proportions, according to the use to which the bricks are to be put.

A great variety of mills are used for grinding the shrunk dolomite. In England the use of the Chilian or edge-mill is general, while on the continent either the Carr or the Vapart apparatus, which is a centrifugal machine, is employed. In order to make the bricks, or the concrete used for the furnace or converter-linings, which are

made exactly in the same way, the ground calcined limestone and dolomite is brought in barrows or conveyors to the place where it is to be used, and dumped on the floor, which is covered with plates of iron and sprinkled with dolomite dust to prevent the tar sticking to it. It is mixed with from 3 to 12 per cent. of tar, according to the purpose for which it is destined. For ordinary bricks one bucket of tar is generally added to ten or fifteen of dolomite, according as the mixture is to be more or less dry. In most of the works the tar is carefully boiled to expel any water or ammonia that it may contain, for fear that this might cause the disintegration of the bricks if allowed to remain. This is done in a boiler, and when the water and ammonia have been driven off, the tar is pumped into a vat from which it can be readily drawn when wanted. In other works it is claimed that it is useless to boil the tar, either for the bricks or for ramming, as all the water is expelled when the bricks are burned or the ramming is fired; but most makers are justly very particular about it. When properly done, the bricks made with the boiled tar last the longest.

The shrunk dolomite, crushed to about pea-size, is made into a hollow pile, and the tar poured into the center from a bucket and roughly mixed with a shovel. In some works the shrunk dolomite is shoveled into a hopper and the tar allowed to run on it until the workman judges by the eye that there is enough, but in such cases they often make mistakes about the quantity, and are obliged to add either more tar or more shrunk dolomite. The mixing is done differently in different works. On the continent the use of the Vapart mixer is almost universal. This consists of a helix run by a belt and set in a cast-iron cylinder, at one end of which there is a hopper for charging, and at the other a discharge-opening. The bottom of the machine is set $0.60^{m}$ above the ground at the discharge-end so that the top of the hopper is about $1.80^{m}$ high. Two men work the apparatus, one doing the mixing and the other the charging. The mixed material is carried away by a third man. The screw of the mixer is about 6 feet long, and discharges the material in a heap at the other end. The men are made to do the mixing themselves, and when by mistake too much tar has been added they mix it with the shrunk dolomite dust and put it back again through the machine. It is discharged from the other end of the mixer into a little heap on the iron floor in a very thick pasty condition, and is immediately carried in barrows to the place where it is needed. It is mixed only just as fast as it is required for use. This mixture is stiff when cold but soft

when heated. When it is to be used as slurry a little more tar is mixed with it, so as to make it run very slowly when cold but be quite liquid when hot. The amount of fine dust will vary with the apparatus used. Generally it will be about one-third of the volume of the material which is put into the machine.

At the Northeastern works, where all the work is done by contract, the Vapart apparatus has been discarded as too difficult for use and as not giving good results, for occasionally when the men are careless with it, filling it too full or trying to make it do too much, it gets clogged and refuses to work. This will generally happen when the quantity of tar is such as to make it stick to the screw. It then takes some time to empty the machine and start it again, and all the material has to be remixed and passed through a second time. At these works the mixing is done with a shovel in front of the edge-mills, the pans of which are set in motion and cause the revolution of the wheels. The shrunk dolomite and tar, approximately mixed, are put into the mills, which are provided with followers, so that the material is constantly pushed under the mill, and when it is sufficiently ground and mixed it is removed from the front by a shovel. When removed, or even while it is passing under the mill, the men judge by the look and the feel of the mixture whether more or less tar is required. This method avoids all the dust which is usually caused when the grinding and mixing are done separately. The only objection to it is that as the pieces are only coarsely broken in a crusher, the sizes of the material are not uniform, and pieces the size of a hazelnut or larger can be easily seen in the ground and mixed material. Care must be taken to avoid having too much dust with the coarse. It has been found advantageous to have coarse and fine together; when coarse alone is used the bricks made do not have sufficient consistency, and when too much fine is used, it takes up too much of the binding material. For ordinary bricks, the mixture is one part of tar to ten of shrunk dolomite.

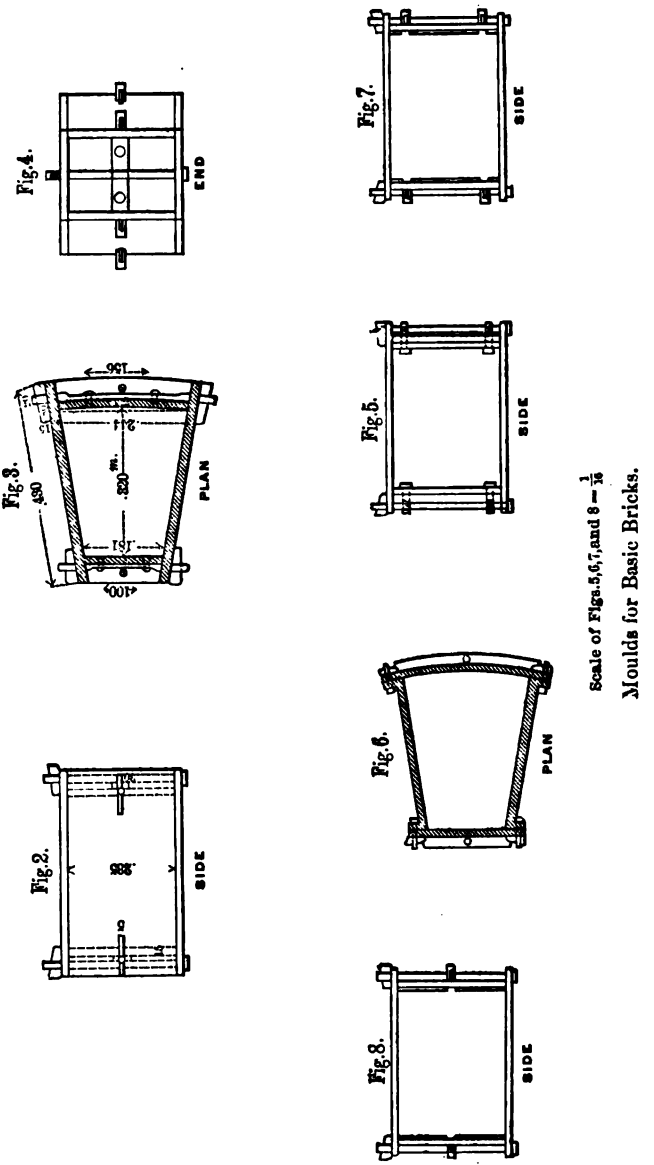
The mixture thus formed is afterwards made into bricks of the desired shape, or else used as a concrete and stamped into the place where it is to be used. When this is to be done a form is put in on the inside, adjusted so as to leave an equal space between it and the sides of that part of the furnace or converter, and the material is carefully stamped in with hot irons.

The manufacture of the bricks requires special care. They are made in iron moulds, a special one being required for each shape of brick made. They are so arranged that by driving out keys from

cotter-bolts they readily fall apart, and are as readily put together by reinserting the keys. In many of the older basic Bessemer works there are six sizes of these bricks; but the effort is now being made to simplify the construction of the converters, so as to bring down the number of sizes to two or three, which differ mostly in the length of their radii, so as to fit the curves in different parts of the converter. The number of shapes required for use in an open-hearth furnace will not be more than two, since the surfaces are either flat or so slightly rounded that the bricks can be easily made to fit. The iron for the tops, bottoms, and sides of the moulds is cut from boiler-plates with projecting ends, into which a slot is cut for the insertion of the keys, as shown in Figs. 2 to 8, inclusive. The plates are bent to shape and flanged so as to project enough to admit of two long bolts which hold the top and bottom together, and are keyed with iron keys which can be readily knocked out. The bottom piece projects enough for the bolt to pass the sides. The top, which is of the same size as the bottom, is laid on and keyed in. Formerly the iron for the sides, top, and bottom was simply flanged and put together by cotter-bolts. This took so long a time that it diminished the possible number of bricks that could be made in a day. To remove this difficulty, the present very simple method was adopted. Of these moulds there are two general types, as shown in Figs. 2 to 8. These look very much alike, but the use of the type shown in Figs. 2, 3, and 4, which is that employed at the Northeastern works, effects a great diminution in the repairs, as well as a very considerable increase in output, as they can be much more readily put together and taken to pieces than the older pattern, and are less likely to get broken and consequently need fewer repairs. They are made so as to have fewer keys than elsewhere, and they consequently last much longer and are more easily taken apart. They last with but little repair for six months.

At first it was considered necessary to clamp the moulds in place so as to prevent their slipping. This was done by bolts with long washers and a nut fastened to a hinged iron piece screwed to the table on which the bricks were made. The mould was first clamped in and then filled. The bricks are now made in most of the works on the cast-iron floor or on blocks of wood 0.12$^{m}$ high, in which depressions are cut to fit the projections of the mould. This raises the mould from the floor. This method takes such a large amount of space, as every man takes all the room he wants, that at the Northeastern works the bricks are made on platforms of red brick 20

inches high, covered with cast-iron plates 1 inch thick, with lugs underneath so as to fit into the brickwork. The plates are 36 by 40 inches, which is all the space allowed to one man. In the center




Scale of Figs.5,6,7, and 8 — $\frac{1}{16}$

Moulds for Basic Bricks.

of the plate there are two long oval holes and six small ones, so that the brick mould will not slip about, as the projections on it fit into these depressions. There are three such platforms, each one

having places for five men. Two of these platforms are together, placed at right angles to each other, and detached from the third. This method concentrates the work of making the bricks in a very small space, but large enough to do the whole of the work well, and permits a complete supervision of all the men. The iron moulds with the top open are placed on the platform in the depressions made to receive them. In some works the sides of the mould are roughly smeared with oil to prevent sticking, but this is not usual. The mixture is then shoveled in in small quantities at a time and pounded with red-hot irons, Fig. 9, *a*, *b*, *c*. The stampers for ramming are all heated in a stove, Fig. 10, in which coke is burned. It stands in the place most conveniently reached by all the men. It is square, and has nine to twelve holes on each side. The rammers are put in here until they are red-hot,* and then used. The handles, while the ends are in the stove, are held up by a bearer, Fig. 11, made of iron and three rows high. The ordinary stampers for bricks are everywhere made alike, but those for the plugs have a hole through the middle or cut out of the side. They are about 0.08$^{m}$ square, having a handle 1.5$^{m}$ long, and weigh from 5 to 6 kilograms each. They are used with both hands, the bricks being the better the harder they are beaten.

Care must be taken not to put too much of the mixture in the mould at any one time, as there would be danger of layers forming which would afterwards separate when the brick came to be used. In order to avoid this the mould is filled only one-fifth full, and is then stamped. When this is done the surface should be made rough with a knife or a point; but this is not usually done, especially when the bricks are made by contract. The mould is filled in five stampings. When stamped full the cover is keyed on, so that the brick is completely inclosed in the iron case. At the Rhine works six men are employed; each man makes twenty-five in a day, and is paid 16 pfennings each, the overseer 1 pfenning per brick. The cost of these bricks at Hörde is 1.20 marks per ton of steel. Here each man is expected to make twenty bricks in ten hours, and if for any reason the bricks are not made in the given time he is expected to remain until they are done. In England each man makes twenty-two in a day. At the Northeastern works ten men work on the two platforms, at right angles to each other, and five on the other, or fifteen

* They need not be red-hot, but it is a little more convenient to have them so. They should in any case be so hot that none of the material will stick to them.

men making bricks, Figs. 2 to 8. One man brings the material and

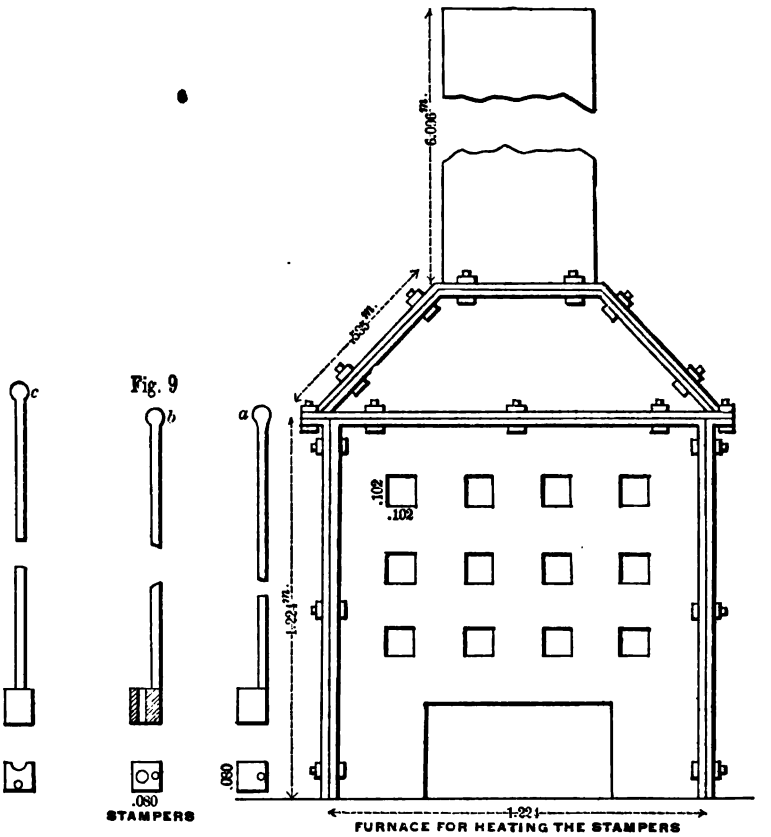
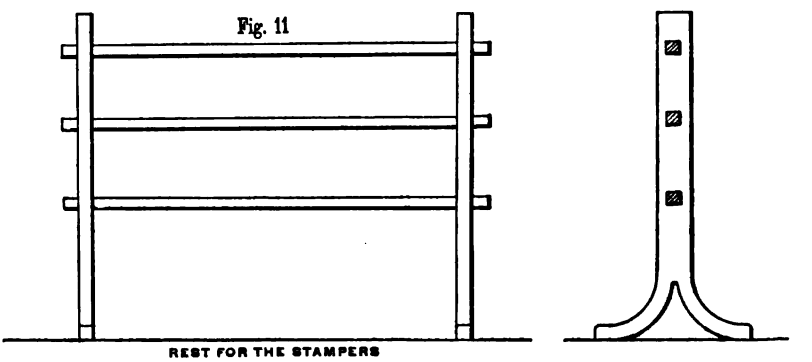



Fig. 10



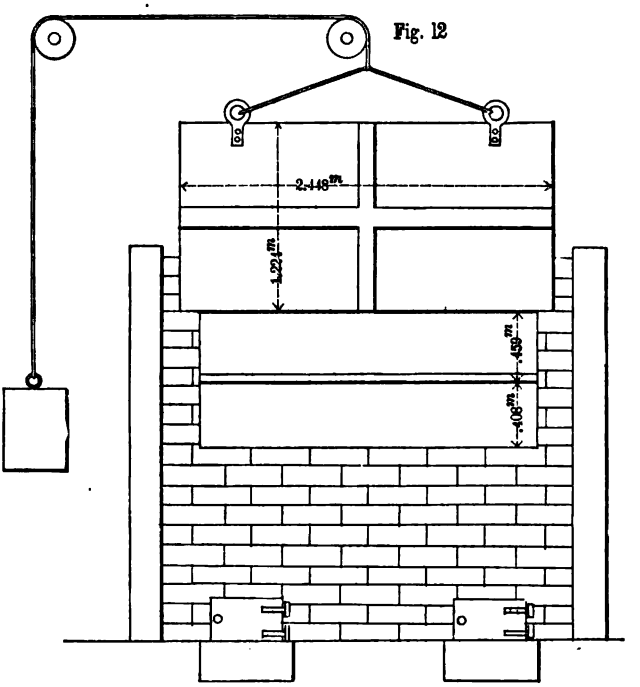

Apparatus for Stamping Bricks.

one man shovels it into the moulds for the ten. Each man when

working at piece-work can make two to two and a half bricks in an hour. When they work by the hour they do much less. The moulds cost 17s. 6d. each in England. The cost for the mould per thousand bricks is 3 pence. Filled, it weighs 80 pounds. Each brick weighs about 55 pounds.

The manufacture of the bricks would be better and more quickly done by proper hydraulic machinery. I have not seen any experi-

Fig. 12




Furnace for Burning Bricks.

ments made in this direction on large-sized converter-bricks, but I am quite certain that the results would be satisfactory.

The bricks in the moulds are caught by a grampus and dragged over the floor to the front of the furnaces, Fig. 12, in which they are to be burned. These furnaces have a down-draft. They are alike in nearly all the works, the dimensions of the principal ones being given below. They differ only in the fact that in most of the English works the interior of the furnace is divided into two parts by a horizontal partition of railroad rails set about 0.10$^{m}$ apart, while those on the continent have no such division. At Hörde the furnace is 1.50$^{m}$ high, 1.50$^{m}$ long, and 1.50$^{m}$ deep, arched at the top, with a small fire-place at the bottom. It is closed with iron doors

lined with fire-brick 4 inches thick. It takes eight men four hours to fill the furnace ready for burning. Such a furnace when full holds 60 to 65 bricks, which will weigh about 30 cwt. They are fired in the evening from a small fire-place below, and the day's tale of bricks is burned during the night. The tar burns out in about three to six hours, but the furnace has to cool down before it can be discharged, so that the firing takes twelve hours, and only one turn can be made in twenty-four hours. The temperature in the furnace does not rise much over 300° C. The bricks undergo very little shrinkage. They are discharged the first thing in the morning, and taken at once out of the moulds by knocking out as many of the keys as is necessary to deliver the brick. It takes several hours to discharge the moulds. It will generally be 11 A.M. or later before they commence to stamp the new bricks for the day.

When the furnace is opened the bricks are discharged hot. Two men do this work; one, with a small spadelle having a long handle, brings the bricks to the front, one holds the spadelle, and with the help of the other slides them over the platform upon a pile of slurry in front. The men handle the hot moulds with gloves or cloths, and open them at once, removing the top and one side. If the brick does not deliver, another side is taken off. As soon as the brick is out, the sides are replaced and the moulds sent back to the platforms, and the men commence at once to make new bricks. The furnace is turned very rapidly, it being discharged every fourteen hours. When finished each brick will weigh about 25 kilograms. They are carried at once to the place where they are to be used. Two furnaces will be sufficient to burn all the bricks required for a production of 3000 tons of converter-steel per month. The amount of fuel required is 15 cwt. per ton of bricks burned.

The bricks are used as quickly as possible to prevent their disintegration in the air. When very well made they can remain in the air for about three weeks, but usually in winter they disintegrate in about six days, and in summer in three. For this reason only just enough are made to keep one converter ready for work. The sooner the bricks are used the better. They will easily keep fifteen days, and when well made have been kept longer, but it is never wise to keep them in stock, as they fail much more rapidly than the shrunk dolomite, and can easily be made as required. I saw at Bolckow Vaughn's at Eston a freshly lined basic converter which had not been used, but had remained in place for six weeks while the works were idle. The whole of the bricks had in that time completely slacked.

The bricks taken from the furnace or convertor when it is repaired are broken up and used over again. In a few works they are burned in the cupola with the dolomite, but in most of them are simply ground without burning, and then mixed with the other dolomite. In the Northeastern works the shrunk dolomite is used exclusively for bricks. All the old bricks are re-ground, but this material is used exclusively for slurry or for ramming. Occasionally some slight slacking is observed in some of the pieces which then show a whitish appearance in the slacked part. Such material should be reburned as the slacking shows too long an exposure to the air. The bricks so prepared are used in the cupola furnace, where they require no special description, in the open-hearth furnace, and in the basic Bessemer converter.

Experience with the basic open-hearth furnace is confined to a few works, and but little is known of it except from the practice of a few works in England and on the Continent. The practice is less difficult than that of the converter, but there is also less experience of its working, and a description of it will, therefore, be interesting. The furnaces employed have been usually altered from furnaces with siliceous linings. This can be easily done when the lining is removed. The interior construction and, to a certain extent, the exterior also, require to be slightly different in the case of the basic lining, as compared with the acid, because the lining has to be made of two totally different refractory materials. In order to separate the phosphorus and withstand the reactions on the hearth, it must be made of basic material, while, in order to withstand the high temperature at the roof, that has generally been made of acid material.* The difficulty is not in the formation of the interior, but to prevent the fusion of the two different materials at the line of junction, which would necessitate frequent and extensive alterations and repairs to the furnace. To overcome this difficulty, the hearth is put in first, and is entirely independent of the roof, the latter being supported on iron projections attached to the side of the furnace. The hearth is brought up to near this point of junction, and a special refractory material stamped between it and the roof. This material, in the works in Russia, Poland and Terre Noire, and some of those in England, is chrome-iron mixed with tar, rammed tight between the two. This is so infusible that little or no chemical action takes

* A roof has been made of magnesite, but it was very expensive, and quickly failed, from defects which might have been remedied, if it had been worth while to continue the experiment.

place, and the repairs required to it are very easily made. In England, at the Farnley iron-works near Leeds, and at Creusot in France, the junction is made of bauxite, ground and mixed with tar in the same way, and causes no special difficulty.*

The construction of the hearth is different in different works. At Farnley,† the ramming made of burned dolomite and tar is first stamped over the bottom to the depth of about one-third of the total depth of the hearth. Over this tar-bricks are built in in a step-shape so as to leave an irregularly shaped bottom, on which the final hearth is afterwards to be made. On the sides and against the siliceous lining and the material of the air and gas ports, is placed first, a lining of bricks made of calcined magnesia mixed with tar, and next it, coming in contact with the basic material, a bed of bauxite prepared in the same way. While the lining is being made, wooden plugs are placed for the formation of the tap-holes. To isolate the basic material from the roof, which is made of Dinas bricks, the bauxite is rammed against the roof, being about twice the thickness of the magnesia ramming below. When the furnace is completed thus far, it is lighted, and in about seventy-two hours is ready for the formation of the bottom of the hearth. This is made by first mixing freshly-ground burned dolomite with ten per cent. of ground fire-brick so as to give a sufficient fluxing material for binding together the upper and lower part of the furnace bottom. The heat has been sufficient to burn out the blocks of wood used for forming the tap-holes, and the holes are stopped either with dry lime or lime mixed with a small quantity of powdered coke. The ports need repair every eighteen to twenty days. The side-walls on the side of the tap-hole last from thirty-six to forty-five days. The hearth of the furnace requires repairs when the side-walls are repaired. In the other English works, the bottom is entirely rammed. At Dombrowa the hearth is made entirely of bricks with the coating above. At the Alexandrowsky works near St. Petersburg,‡ the gas and air-channels are first put in in Dinas brick. Ramming is then stamped over the whole iron bottom to a depth of 25$^{cm}$; as many pieces of shrunk dolomite as can be put in are bedded in this mixture. A wooden wall is then arranged around the sides of the furnace parallel to them, but at a distance from the bottom of 46$^{cm}$ and at the top of 29$^{cm}$, and into this space

* "Basic Open-Hearth Process," *School of Mines Quarterly*, October, 1885.

† *Proc. Inst. Civ. Engs.* London. Vol. lxxvii., part 3.

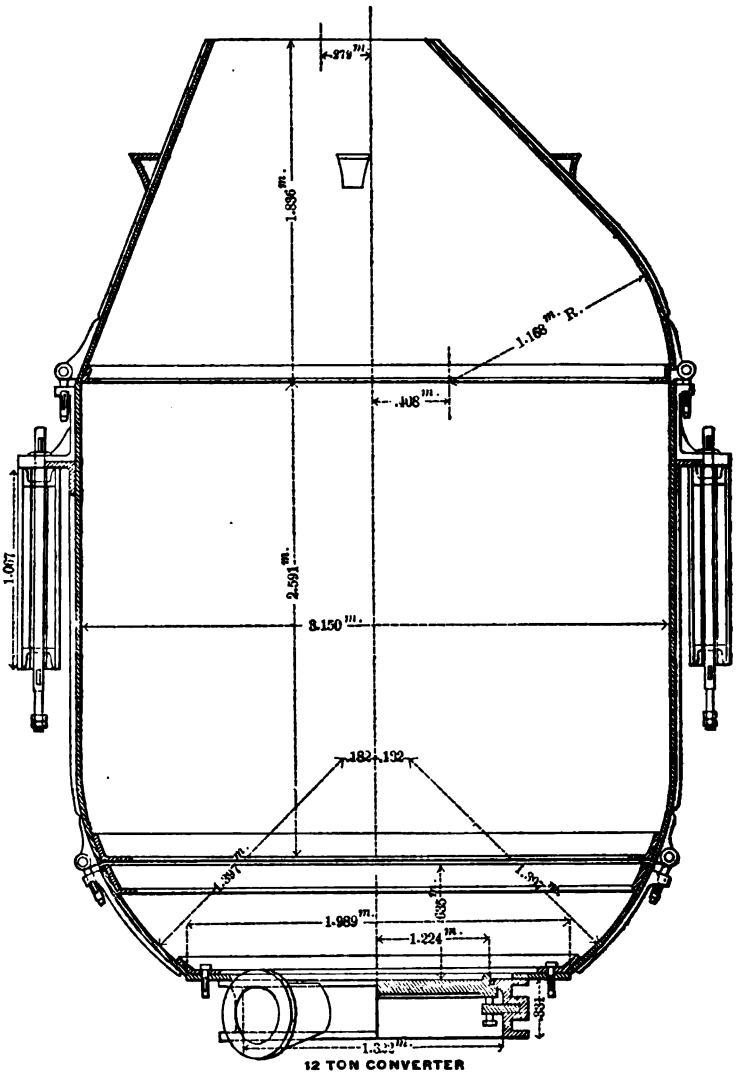
‡ *Eisen und Stahl*, Vol. ii., p. 599.

the mixture, made of pieces of dolomite about the size of a walnut, and mixed with 7 to 8 per cent. of coal-tar, is stamped. Experience has shown that the harder the dolomite is burned, the less tar is required, and the finer it is ground the more tar is necessary to make the mixture resisting. The wooden plugs are put in to form the tap-holes, while this stamping is going on. It has been found necessary in stamping in, that the beds should not be stamped more than 5$^{cm}$ in thickness at a time, as with that thickness the adherence between the layers can be made perfect by the blow of the hot and heavy stamper. When these walls have been brought up to their proper height, a ramming made of chromic iron mixed with tar and 15$^{cm}$ deep is stamped in, over the iron support of the roof, which is made of Dinas brick, and between it and the basic work below. This is constructed in three arches put together without any mortar or other binding material. The ports on each side, and about one-fifth of the hearth on each side are covered by the side-arches, and the remaining three-fifths in the center by another arch. The object of this construction is to enable repairs to be made to one part without touching the others. When the whole furnace is ready, short pieces of rails are placed over the bottom of it, so as to cover it as completely as possible. The side-walls are protected with pieces of boiler-plate which are supported in place by rail-ends leaning against them. The furnace is then heated; the bottom and sides being protected from the air, the tar is only burned out when the mass has been brought up to a point where it will frit. Without this protection the sudden burning of the tar would cause the lining to crumble before it had become compact. The iron protection is not removed from the furnace until just as it is about to melt. After the removal of the iron, the firing is kept up until the hearth is quite hard, as it will be by the time that it is at a white heat. This will take about a day and a half when the furnace is fired with wood, and two and a half days when it is fired with gas. The charge in these furnaces is about six tons. The bottom of the hearth will stand from 150 to 200 charges. The side-walls and bottom have to be repaired with ground shrunk dolomite after every charge. The tap-hole has to be repaired every three or four days if only 2 charges are worked out in twenty-four hours. The gas and air-ports have to be frequently repaired with a mixture of coke-dust and coal-tar.

The work of lining a converter is much more complicated, and as access can be had to every part of it, and as different parts wear differently, it is designed with special reference to the facility of lining

it. The converter, Fig. 13, in all the recently constructed works consists of three parts, the upper part or cone, through which the casting is made, the body or middle part, and the ring or bottom below it, which holds the plug containing the tuyeres. These can

Fig. 13.




12 TON CONVERTER

not only all be detached from each other, but also from the trunnions, so that each part can be taken into the brick-shop to be repaired while another is put directly in its place. In most of the acid works which have been altered to basic, only the bottom is movable, so that

the body with the cone attached, to be relined, has to be turned over and relined in place. In some of them the cone is also movable, and the body alone rests on trunnions. It is always better to have all the parts movable, as it is not always convenient to reline in place, especially where the slag is dumped in the pit.

The shape of the converter is a matter of some importance. As the action is much more tumultuous in the basic than in the acid process, the nose projecting over the side has been abandoned and the conical form used. Experience has shown that it is best not to place the axis of the cone in the prolongation of that of the body but a little to one side of it, and in this way avoid as many of the projections from the center as possible, and that it is desirable to give the converter more motion than in acid works. Thus, at Eston it has a motion of 360°, and can be swung one way or the other. Most of them are required to move 180° either to the right or left. This motion is desirable because the side opposite to the casting-pit, which is always bare when the converter is turned down, wears more rapidly than the other, never having the protection of slag such as the opposite side has acquired from the slag remaining behind when the steel is run into the ladle. This slag is all subsequently melted off, but during the first part of the operation as it is not very fusible it protects that side while the other would be bare. By casting the slag on one side and the steel on the other both sides are equally protected. As the slag is so slightly fusible, the nose becomes constantly obstructed, and after every operation these engorgements have to be removed, which takes time. The opening of the nose is for this reason lined with acid bricks so that it can be repaired with clay. A great advantage of the conical form is that it requires the least possible number of sizes of bricks. Being made in three pieces only, the converter can be easily put together and the surfaces of junction made tight. As the parts do not wear uniformly, with such a disposition any one that requires repair may be replaced and repaired at leisure. This is all the more necessary as the cooling takes more time than it does with the acid converters, which could be cooled off with water, which would be impossible with the basic lining, as it would slack. Each piece can be set away to cool until it is ready to be repaired.

The converter is lined in two ways, either by ramming or with bricks. The method used depends partly on the supply of brick and partly on the position of the section of the converter. Ramming would undoubtedly be the best method for all parts, but it

takes much longer, requires greater care, and when not well done is more expensive than filling with brick. The bottom and plug are, however, always rammed. When a shell is to be relined it is turned up as when it is in action. The hydraulic wagon moved by wire ropes attached to a steam capstan is brought under the bottom and that is removed. It is now turned with the cone down which is removed in the same way. The body is then taken away by the great overhead crane, and a new converter put in, in the reverse order.

When the body or the cone are to be rammed, a wooden or an iron pattern is adjusted on the inside, which corresponds exactly to the shape that the interior of the converter is to have. A platform is made on the outside by iron hangers which hook on to the side of the shell, and on this boards are placed. The mixture is rammed between the sides and the ring. It must be beaten with great care, as the surfaces are very large. But little of the ramming is put in at a time. Six men are thus engaged on the circumference so that the work is very nearly uniform. When the whole shell has been carefully rammed, the form, if of wood, is removed, and the converter fired very slowly with coke until the tar is burned out. These patterns are made in segments for greater ease of manipulation. In places where wood is cheap they are sometimes left in after the ramming is completed, and are burned out when the lining is heated. Generally, however, the form is made of iron. A fire is made in it, as is done for the cone. This is a much better method. Occasionally the body is made partly of brick and partly of ramming. This is, however, only done when the bricks give out, and delay is impracticable. It has all the inconveniences of both methods, and none of the advantages of either.

When the converters are adapted from old acid works, the body and the cone are often made together, the bottom only being removable, but when they are built for the purpose each part is separated and treated separately. When the body is to be lined with brick at the Staffordshire works, they arrange the platform around the outside of the body, exactly as if ramming was to be used. The bricks are brought to the platform and handed down into the inside of the body. They are placed against the shell with 2 or 3 inches space between them and the outside. The space between the shell and the brick is then rammed, care being taken to break joints in the rows of brick. The converter holds 491 bricks. When there are not enough bricks they sometimes ram a ring and put in a ring of bricks. Four men can line a converter in two days. A converter

so lined with brick should last, with repairs, 50 to 60 blows. They actually last from 30 to 35. When the upper part has been freshly lined the lining is held in place, at the South Staffordshire works, by an iron ring held in its place against the bottom of the bricks by lugs, which turn down from the outside of the shell. When the converter has been working, and a new bottom is to be put on, the lining is so thoroughly burned that it will hold itself, and this ring is removed. At the Northeastern works an iron ring is permanently attached to the shell which just catches the back end of the bricks and supports the ramming. Generally the body is placed on a bogie raised high enough above the ground so that all the material can be put under it. Two men then get in the inside and lay up three courses of brick and ram them. The bricks are laid touching each other with nothing between. They are not always even in front. After the three first courses as many men as can work get inside. This will be four or five at least. After a number of courses have been laid up both the ramming and bricks are brought to the top of the shell in baskets carried on a man's head. He climbs a ladder with it and delivers the contents on the inside where they are wanted. It would be quicker and better to make some arrangement with the crane to carry a large number of bricks, and a considerable quantity of ramming, for the men are often idle for want of material. As, however, the work is done by contract but little attention is paid to this.

At the Northeastern works, all the bricks required for lining the shell are piled up in a heap with the ramming that is required. The body is brought by the overhead crane and set over them. The men get inside with ladders and do the work. The layers of brick are put in rather loosely, and then are pressed out from behind with crowbars, and the mixture rammed in. As the sides of the brick as they come from the furnaces are nearly plane surfaces this makes the joints quite tight. The first three rows require to be laid up with special care. Only the back end of the bricks is supported by the ring on the shell, and if they were not carefully put in the whole lining of the body might be endangered. In some works the body is rammed. This is more quickly done than by the use of either dolomite or magnesia bricks, but it is more uncertain. When it is well done, however, the lining lasts quite as long. With bricks the whole converter can be relined in about eighteen hours.

Sometimes the lining of the body is so much worn that it is not safe to use it, but too little to justify taking out all the brick.

To repair it, an iron pattern, corresponding to the exact shape of the inside, is heated and put inside the body, which is still hot. Slurry is then put in between it and the old lining. The heat of both pattern and body acting on it, causes the slurry first to run into every fissure and irregularity of the lining, and finally cokes it; after which the pattern is removed. This has to be done slowly and systematically. By this method a body can be relined so as to make only eighteen hours from blow to blow. The slurry which is used for this purpose contains more tar than that used for the ordinary brick. It must run stiff when it is cold, but be very liquid under the heat applied to it, so that it runs like water into every crevice. The material which is used may be the worn-out bricks or the shrunk dolomite mixed with fresh tar. The old bricks ground but not reburned are oftenest used for this purpose. When the plant is so arranged that the body with or without the cone must be repaired in place, it is done either with bricks or by the method just described, that being most convenient, as it does not require the converter to be perfectly cool.

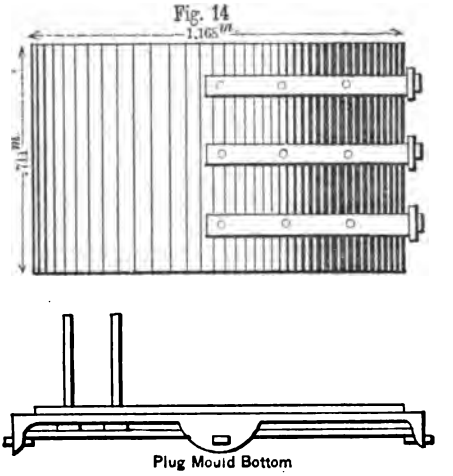
The cooling of the converters to make repairs takes more time than in the acid plant, as water cannot be used. When they are required to remain in place, this is a serious inconvenience. In some of the works a fan-blower with an air-conduit, in which there are a very large number of openings, is used to force the air against the sides and thus cool the converters. This is placed under the converter after the bottom has been removed and the converter turned up. When all parts are movable and there are a sufficient number of them they are left without making any attempt to cool them artificially.

At the Northeastern works the cone is placed upside down and rammed against an iron shell. This shell is made in two parts. The bottom one carries a set of grate-bars. When this has been rammed up, the top section composed of two parts is put in and the upper part is then rammed. When completed the whole is filled with coke and burned for twenty-four hours. Thirty-six hours would be a better time. It is then lined at the mouth with two rows of acid bricks. This work is generally done too rapidly. A more careful and slower ramming would undoubtedly make the parts last longer and diminish the repairs. In most of the works the lining is done with bricks of a very large size so that the work is quickly done, but at Eston the cone is lined with bricks the size of house bricks and rammed. The bottom is also rammed. In

these works the cone is rammed against a mould in two parts, the lower whole, the upper made in small sections. When rammed it is placed on a support covered with a conical cover and blown from below with pressure.

The bottoms of the converters are removable, and are always made of the slurry or concrete. The bottom is the most important part of the converter. It is made of two parts, the ring, and the plug which carries the tuyere holes. These are made and burned sepa-

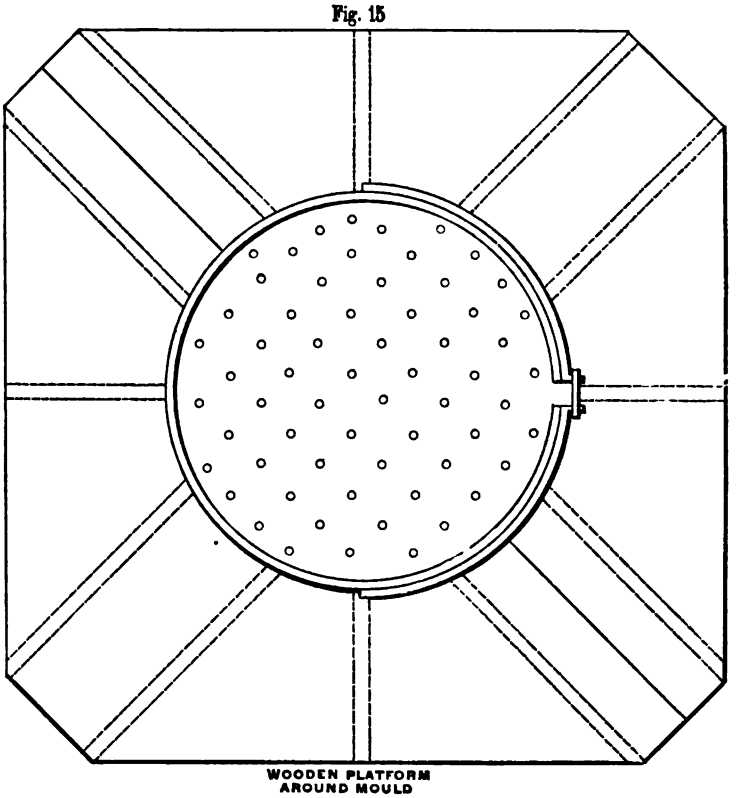
Fig. 14




rately, and the greatest care is required not only in making them, but also in putting them together. The plug, Fig. 14, is made in an iron ring which was formerly made at the Northeastern works in two pieces, and held together by three or four lugs welded to it. It is now made of a single piece and held together by three links which fit over the lugs, and makes a much simpler construction, as it is quickly removed from the plug after it is burned and is readily

adapted again for a new plug. A square bench, Fig. 15, with a circular hole in the center the size of the ring, and made in two parts so as to be easily removed, is placed around it for the men to work on. This ring is set upon a bottom-plate of cast-iron, Fig. 14, which is filled with holes corresponding to the tuyeres. The number of these holes varies in different works and varies also with the size of the converter. At the Rhine works there are 45 of them 0.015$^{m}$ in diameter. At Glengarnock there are 56, and at the Northeastern

Fig. 15




works there are 62, which are 0.02$^{m}$ in diameter. These holes are regularly distributed in the plate. Through them iron rods with heads to prevent their coming through the plate, of the same diameter and a little longer than the length of the tuyere, are placed. This cast-iron plate with the rods in the holes is placed upon a support so that the heads of the rods cannot fall out (Fig. 14), and the ring placed on it so as to leave the cast-iron plate projecting

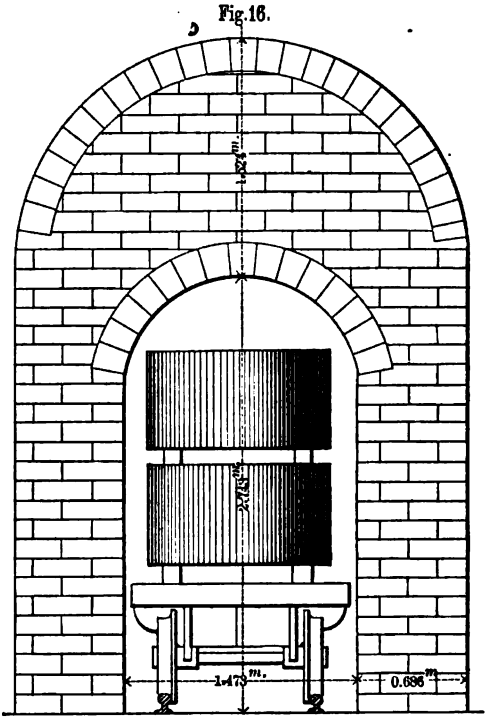
0.02$^{m}$ to 0.03$^{m}$ beyond it. The ramming is shoveled into the ring and pounded with the stampers, in the same way as for the manufacture of the brick, only as the piece is much larger and there are to be holes in it, much greater care is required in making it.

At first the same stampers were invariably used for making the ring and plug which were used for making the bricks. It was then found that the abrasion by the blast was very great because the point where the material was least compressed was directly around the holes made by the iron rods. The stampers being all of the same size and shape, Fig. 9 *a*, the men were required to stamp against the rods, and to go constantly round them to get an equal pressure on all parts. Each man stamped his part, but it was not the duty of any one in particular to stamp against the rod. The consequence was that the holes wore out rapidly and unevenly in their length on account of the different parts being of different densities. To remedy this defect the stampers were made with a half-circle cut into them, Fig. 9 *c*, in some works, or else had a hole through them, Fig. 9 *b*, a little larger than the size of the tuyere rod, and a certain number of the men used this kind of a stamper, while the others used the ordinary ones. The practice is quite different in different works in this respect, but in most of the works the stamper with a semicircle cut out of one side is used by all the men, care being taken to give the greatest force of the stamping around the rod. The greatest care must be taken that the mixture does not contain too much tar, and that no large amount is thrown in any one place, for fear of having the beds separate in the converter.

The mixture for the bottom and plugs is made of 10 to 15 parts of shrunk dolomite to 1 of tar; the shrunk dolomite used is half powder and half the ordinary shrunk dolomite ground somewhat finer than that used for the bricks. There seems to be little doubt that if the whole bottom were made at one time by pressure it would last much longer than it now does, as it would then all be of the same density and there would be no danger of solution of continuity between the different beds. The plugs when finished are about 1$^{m}$ in diameter and 0.75$^{m}$ high, and slightly conical. They are placed, two high, on bogies, and run into a furnace (Figs. 16 and 17), which holds five bogies, so that there are ten in the furnace at a time. At Bolckow Vaughn's the bogie holds four plugs, placed one on the top of the other, and eight are burned at a time. At the Northeastern works there are three of these furnaces. They are 14 feet high, 4 feet 10 inches wide, with walls 27 inches thick, and 45 feet long.

In some of the works they are so constructed that the bogies with the plugs on them are pushed in at one end and out at the other. When the furnace is full, the doors, which are 9 feet high and the whole width of the furnace, are walled up and the furnace is fired. At the Rhine works this furnace is made of an old gallery on the outside of which three fire-places have been adapted. It is 2$^{m}$ high, 15 to 17$^{m}$ long, and holds 15 of the plugs at a time. In these furnaces the plugs are burned from three days to a week, depending on the need there is for the plugs, about seven days being apparently the best time. When they come out they are red-hot in the center.

Fig. 16.




CROSS SECTION OF FURNACE FOR BURNING PLUGS
Scale — $\frac{1}{25}$

In cooling they sometimes split from top to bottom. When cold they are placed on a circular support, the iron rims are removed and the iron rods are driven out with light hammers. They must be started with light blows, as a heavy blow would only upset the ends without starting the rod, and make it difficult to get the rod through the hole. They fall upon the floor below and are collected at once to be used in making the next plug. They are made of hard

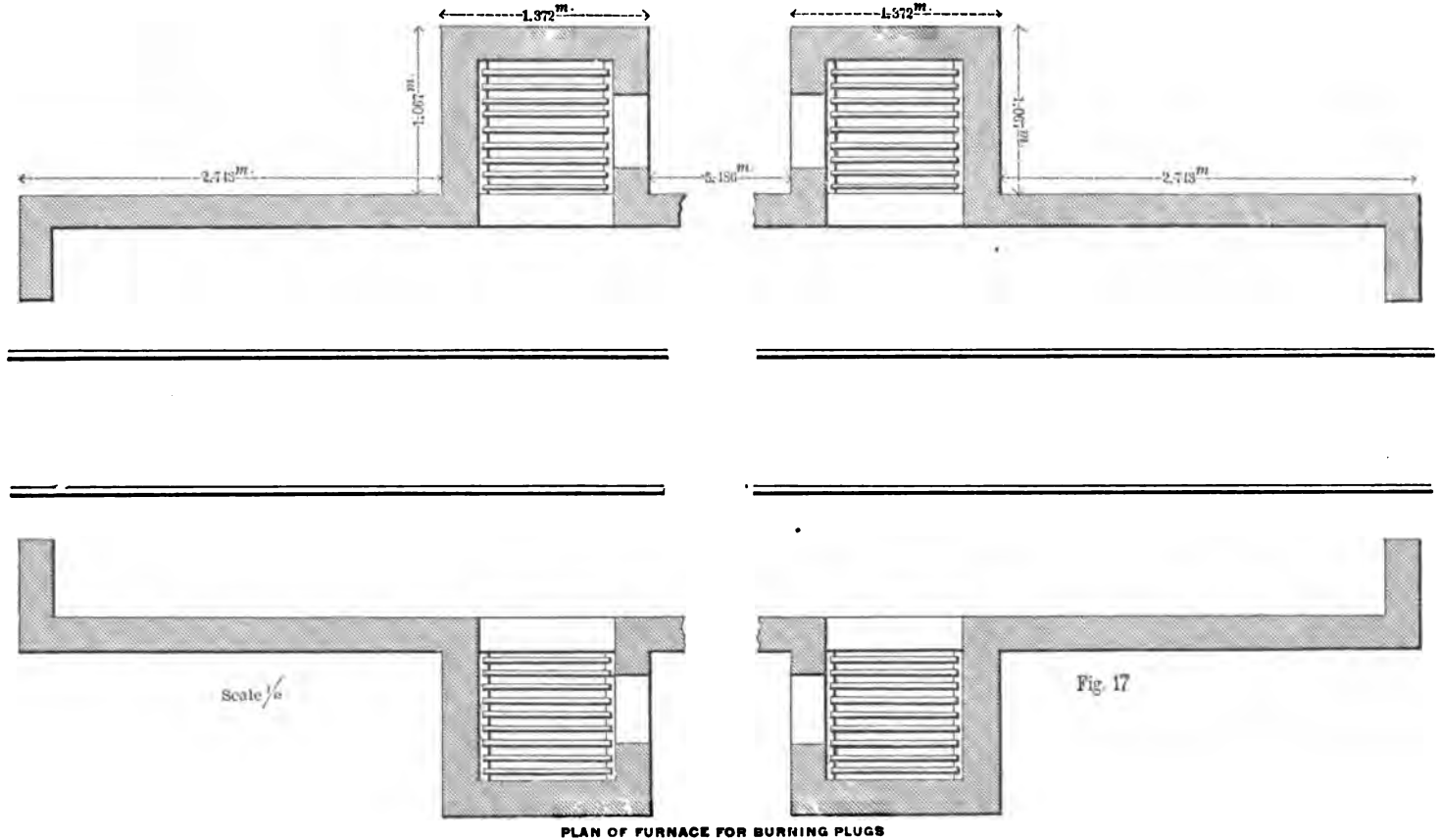



Fig. 17

PLAN OF FURNACE FOR BURNING PLUGS

iron with a head at one end and slightly conical at the other. They have to be repaired every time they are used, and for this purpose are heated in the stove and hammered up at once on an anvil near by. One man is engaged most of the time at this work; he is, however, only a laborer. It is not always possible to drive out all the iron rods. Many of them stick, and where they cannot be driven out except with danger of injury to the plug, they are simply left in. It sometimes happens that 10 or 15 will be left in a single plug. The obstruction of a few of the holes makes no very great difference, but if too large a number of the rods could not be driven out, then the plug would have to be broken up. This, however, very rarely happens. When the rods are removed the plug on its cast-iron bottom plate is ready to be placed in the ring. This bottom plate is used continuously, and lasts a very long time, as it has no wear, and is only subject to the heat of the furnace in which the plugs are burned. It must be carefully inspected when a new plug is to be made, as the steel from the converter sometimes drops through the bottom and fills the holes up. These holes must all be punched out when a new plug is to be made. Generally a light blow is all that is required. At the Northeastern works five men make three plugs per shift. This is working rather faster than is consistent with the best work. At the Rhine steel works and at Glengarnock, four men make two in a day. At the South Staffordshire works, seven men are required to do the same work. Four of these use the ordinary rammers, the three others have rammers through which the tuyere-irons pass, and these ram constantly on the tuyere-irons; the other men ram between.

The rings are always stamped. To do this the iron shell is placed on a support, a circle of sheet-iron corresponding to the plug being placed in the center. They are burned like the plugs. When they are repaired, it is done by stamping in ramming. It takes six men an entire shift to make one. When repairs are to be made to the ring, the upper rounded part is cut off, tar is sprinkled on it to make the slurry stick to the burned portion, and when a little has been pounded on, fresh additions of the mixture are made, and so on, ramming hard at every operation. The joint in this way is pasty and closes. When the whole converter is rammed the operation takes sixty hours from blow to blow. When it is done with bricks alone it takes 15 hours.

In some of the works on the continent, notably at the Rhine Steel Works and at Angleur, the bottom was formerly made in acid mate-

rial and the tuyeres made of magnesia were introduced just as acid tuyeres are used. The process was found to work advantageously, but it required a different set of men making bottoms from those making the bricks, and is now given up. These bottoms are attached to the converter with very little trouble and are ready for use as soon as they are so attached.

In a certain number of cases the ordinary acid tuyeres are used. These are replaced as they are in the acid process, and are cemented in with the ordinary mixture of dolomite and tar. The stamped bottom, however, is found to answer quite as well if not better. The wearing out of the plug is caused rather by mechanical than chemical action. It is always worn out very unevenly. The pitting is generally in the direction of the tuyere holes. There is much abrasion and slagging as well; but there is no sign of slagging anywhere on the lining; what has been chemically combined is carried off in the slag. The rammed is very much softer than the ordinary acid bottom, and wears out much faster. The top of the hole generally becomes very much enlarged and trumpet-shaped, and the blast becomes too scattered to bear the pressure of the liquid steel and there is danger of the charge running into the wind chest. When the plug is well worn the holes close up, as the opening is too large, and there is too little force of blast to keep the metal out. The constant pounding from the motion of the steel wears away the dolomite by abrasion. This can be easily seen from the nose, and when the holes are too much worn the bottom is taken off.

At the Rhine Steel Works the ordinary acid bottom in which the magnesia tuyeres are placed was formerly made by four men who stamp the fire-clay with hot stampers. It takes about as long to make one of these as the basic bottom. The ordinary acid tuyeres are made by pressing the clay into an iron mould. This is brought and fixed in position under an iron press, which is a screw with a heavy wheel. Five men swing this down. At the end of the screw are eight prongs corresponding to the holes in the tuyeres. These are pressed down once and are drawn out by the screw. The work is hard. The men are, however, paid by the piece, and are satisfied to do it. It might be entirely done by machinery and could be done much cheaper. It was thought at these works that there would be an economy in using square tuyeres, but the experiment failed.

When the plug is about half worn through it is no longer safe to use it and a new one must be put in. It then presents a very uneven appearance, being pitted in every direction with holes of

unequal depth. The plug lasts from eight to eighteen blows, and sometimes longer. In some of the works the regular average is twelve to thirteen. When the stamping has been done very quickly or carelessly, it will not last more than seven. Generally the bottom section is not worn out when the plug is. It should last for twenty-four operations. It is repaired by ramming. The body will last from thirty-four to thirty-six operations. It has lasted as much as sixty or even seventy. The cone lasts about the same. At the Northeastern works two extra cones and bodies and four extra bottoms are kept in reserve or are in repair to be put in at once as soon as any part gives out.

When a new plug is to be put in, the old one is broken out by a weight of about 1000 pounds falling eight to ten feet. It sometimes requires three blows to detach it. The bottom and ramming are then pried off with bars. The ramming separates easily from the plate on the bottom.

To put in a new plug it is placed on a pillar, the projecting iron rim around the bottom covered with slurry and wound with a hemp rope. The bottom is then raised by the overhead crane, it having been previously brushed clean and set down on the plug. When it is done properly it goes in at once and is fastened to its place by bolts arranged for the purpose. When it goes in crooked it has to be driven out by the falling weight, the top of the ring being protected with boards. When the plug is in, the whole bottom is picked up by the crane and carried to the proper place to be stamped. Five men stamp the interstices, one man shovels up the ramming. It takes from four to five hours. When it is stamped up and ready, slurry is brought on men's heads in baskets and shoveled round the rim so as to make the joint with the body of the converter. Great care must be used to see that all the water and ammonia are out of the tar used for the filling. An explosion which destroyed a bottom was once caused by the use of tar with which this precaution had not been taken.

To take the converter to pieces for the purpose of making repairs it is first turned up to remove the bottom. In all the works which were converted from the acid plant this is done by a hydraulic lift beneath, such as is in general use, the bottom being delivered on to a bogie. In the latest works, especially at the Glengarnock and at the Northeastern, the bottom is removed on a hydraulic crane wagon, a cover being put over it to protect the men from the heat. This wagon entirely takes the place of the pit lifts, so that the pit

under the bottom is entirely free. By means of tracks and turn-tables this wagon can, not only reach each converter, but any part of the basic shop to which it is desirable that it should go. The different parts are lifted from it by the overhead crane and set down exactly where they are wanted. The converter is then turned completely over, and the nose removed in the same way. The body is then lifted off the trunnions. At the Northeastern works this is done by a 70-ton overhead crane running above the converters, which lifts the body off and places it upon its wagon. All the different parts are brought into the open shop and are there manipulated by a 30-ton overhead crane. The converter is put together in the inverse order, first the body and then the nose, and lastly the bottom. The bogie that carries the two latter is moved by a steam capstan or a hydraulic pusher, and has adjustments on it into which each of the pieces fit, so that when they come up under the converter they fit it exactly. There are 16 lugs on the outside of the converter which fit into ways on the bottom into which keys are driven. The ways are cut to receive the keys as well as the lugs, so that once in, no movement is possible. To give the necessary movement to the blast pipe, both joints are loosened. To secure the cone to the body there are eight places for lugs and keys. There are six holes in short arms to lift out the converter, and sixteen on the bottom to secure it with the keys to the body.

The operation of putting on a bottom is simple. They commence to take one off just as soon as the converter is turned down to cast. By the time that the casting is finished the bottom plate is so much loosened that it is ready to come off just as soon after the casting as the converter can be turned up to the position where it can be reached. At the same time the blast pipe is loosened. The converter is turned down, leaving the bottom plate at the converter level. The crane wagon comes up under the converter and raises the ram up against the bottom. The few bolts which hold it are removed and the bottom taken away, and a new one brought and secured below in the same way that the other was removed. It would not be practicable to put on the bottom plate which has been left on the level above from below. It is turned up on its edge on the platform above and the converter raised so that the holes in the bottom are on a level with those in the plate. Two bars are then inserted through the holes in the bottom plate and in those corresponding to them in the bottom. These are then raised so that the plate slips on the bars to its place. A third bar is put in, two being held after they

are in, by one man. Two or three bolts are slipped in and keyed and the bars withdrawn. The bottom must previously be covered with a mixture of ramming and cut straw which makes a tight joint. By moving the converter more or less up and down all the bolts and nuts become accessible. The men strike the iron of the platform with a hammer to give the signal for raising or lowering during the adjustment. The bottom is always examined with an iron rod turned up at one end and having a pin welded to it, near the handle; the distance between the pin and the end being the exact thickness of the bottom when new. By inserting this rod in the tuyere-hole, and drawing it back to where it catches on the bottom on the inside, the exact amount that the plug has worn away is shown. The plug can be worked down to 7½ inches, but it is not safe to continue the blow after that.

---

## *AN ELECTRICAL FURNACE FOR REDUCING REFRACTORY ORES.*

BY DR. T. STERRY HUNT, MONTREAL, CANADA.

THE application of electricity in the extraction of metals has hitherto been chiefly confined to the electrolysis of dissolved or fused compounds of these by various methods. The power of electric currents to generate intense heat in their passage through a resisting medium has, however, long been known, and the late W. Siemens thereby succeeded in fusing considerable quantities of steel. But it was reserved to Messrs. Eugene H. and Alfred H. Cowles, of Cleveland, Ohio, to take a new step in the metallurgic art by making the heat thus produced a means of reducing in the presence of carbon the oxides not only of the alkaline metals, but of calcium, magnesium, manganese, aluminium, silicon, and boron, with an ease that permits the production of these elements and their alloys with copper and other metals on a commercial scale.

In the apparatus devised and now employed by the Messrs. Cowles, a column of fragments of well-calcined charcoal, so prepared and arranged as to present the requisite electrical resistance, is imbedded horizontally in finely pulverized charcoal, and covered by a layer of the same material coarsely broken, the whole being arranged in a box of fire-brick, covered with perforated tiles and opened at the ends to admit two carbon electrodes an inch and a half in diameter.

Through these, the current from a dynamo-electric machine of 30 horse-power is now made to traverse the central core of carbon fragments, whereby such a temperature is at once produced therein that platin-iridium may be instantly melted, and the most refractory oxides already named are not only fused and volatilized, but reduced to their elemental state, with formation of carbonic oxide gas.

If alumina in the form of granulated corundum is mingled with the carbon in the electric path, aluminium is rapidly liberated, being in part carried off with the escaping gas, and in part condensed in the upper layer of charcoal. In this way are obtained considerable masses of nearly fused aluminium, and others of a crystalline compound of the metal with carbon. When, however, a portion of granulated copper is placed with the corundum, an alloy of the two metals is obtained, which is probably formed in the overlying stratum, but, at the close of the operation, is found in fused masses below. In this way, there is got, after the current has passed for an hour and a half through the furnace, from four to five pounds of an alloy containing from fifteen to twenty per cent. of aluminium, and free from iron. On substituting this alloy for copper in a second operation, a compound with over thirty per cent. of aluminium is obtained. Already, the small experimental plant, with a 30 horse-power dynamo, is producing daily over five pounds of aluminium in the form of a rich and brittle alloy, which, by suitable additions of copper, is converted into different grades of aluminium bronze. The valuable qualities of these are so well known that it is only their great cost hitherto that has prevented their more general use in the arts. They are now offered for sale at Cleveland on a basis of five dollars a pound for the contained aluminium.

The reduction of silicon is even more easy than that of aluminium. When siliceous sand, mixed with carbon, is placed in the path of the electric current, a part of it is fused into a clear glass, and a part reduced, with the production of considerable masses of crystallized silicon, a portion of this being volatilized and reconverted into silica. By the addition of granulated copper, there is readily formed a hard, brittle alloy, holding six or eight per cent. of silicon, from which silicon bronzes can be cheaply made. The direct reduction of clay gives an alloy of silicon and aluminium, and with copper, a silico-aluminium bronze that appears to possess properties not less valuable than those of the compound already mentioned. Even boric oxide is rapidly reduced, with evolution of copious brown fumes, and the formation in presence of copper of a boron bronze, that promises to

be of value; while, under certain conditions, crystals of what appears to be the so-called adamantoid boron are formed. In some cases, also, crystalline graphite has been produced, apparently through the solvent action of aluminium upon carbon.

Remarkable results are got by alloying small quantities of aluminium with an admixture of copper and nickel. One of these compounds, designated as Hercules metal, broke with a strain of 111,000 pounds to the square inch, with an elongation of 35 hundredths, while a ten per cent. aluminium bronze broke with 109,000 pounds. An addition of from two to three per cent. of aluminium to brass greatly increases its tensile strength, and renders it less susceptible to oxidation. While fifteen or twenty per cent. of aluminium with copper yields a brittle compound, an addition of ten per cent. of copper gives to pure aluminium a great increase of hardness and tenacity, forming an alloy that may have a wide application. It may be added that the difficulties in the way of getting together the reduced aluminium without the aid of the copper promise to be overcome at an early day, so that we may expect the cheap production of such alloys and of pure aluminium.

The Messrs. Cowles, in their later work, have been aided by the chemical skill of Prof. C. F. Mabery, now of Cleveland, who is associated with them in one of their patents. These now cover not only the reduction of aluminium, silicon, and boron, as described, but the extraction of manganese, magnesium, and the alkaline metals by the electric furnace. I had the pleasure of hearing Professor Mabery give the first scientific notice of this discovery before the American Association for the Advancement of Science, at Ann Arbor, August 28th, and then spoke of the early results of Deville and those of Debray on aluminium and its alloys, having myself witnessed many of the experiments of both of these chemists thereon. I also insisted that the importance of this new instrument that the Messrs. Cowles have placed in the hands of chemists, for producing and controlling degrees of temperature never before obtained, can scarcely yet be estimated, either in its economic or its scientific aspect. This heat of the furnace realizes the dream of the alkahest, or universal solvent of the alchemists, and he who can rightly use it will be worthy of the ancient title of *Magister Magnus in igni.*

I may add that, through the courtesy of these gentlemen, I have since been enabled to spend two entire days in their experimental works at Cleveland with the brothers Cowles and Professor Ma-

bery, when they explained to me several points not yet made public, and allowed me to direct experiments with one of their furnaces. The fusion of quartz and the reduction of silicon without the presence of copper was repeated; also the reduction of boron and the formation of boron bronze, with many other interesting experiments. I then suggested trials for the reduction of titanium, both from rutile and from titanic iron ore, which will probably soon be made.

The present plant at Cleveland is but a first experimental one, and has only been in operation a few months. The Cowles Electric Smelting Company has secured a large water-power at Lockport, New York, and a dynamo-electric machine of 125 horse-power is now building for them at the Brush Works in Cleveland, which will soon be in operation at Lockport, and will permit the establishment of the electric furnace on a larger scale. A series of experiments of the products got by this remarkable discovery is, by the courtesy of these gentlemen, placed before the members of the Institute.

---

## *NOTE ON THE APATITE REGION OF CANADA.*

BY T. STERRY HUNT, MONTREAL, CANADA.

SINCE the date of my previous paper on this subject, presented at the Cincinnati Meeting, February, 1884, and published in our *Transactions*, vol. xii., p. 459, I have had occasion to revisit the Canadian apatite region, and to collect further data concerning its geognosy, which I hope to describe at a future time. At present, I shall put on record a few brief observations concerning the more recent operations in apatite-mining in the Lièvre district, to the north of the Ottawa River, where the mines are as yet confined to a small area in the townships of Buckingham, Portland, Templeton, and Derry; the earlier workings having been along the Rideau Canal, to the south of the Ottawa. The large mining operations lately undertaken in the Lièvre district show that the crystalline phosphate of lime or apatite belongs to lodes of great size, which traverse the ancient gneiss of the region. These lodes include a granitoid feldspathic rock, and a pyroxene rock, with large masses of quartz, of carbonate of lime, of pyrites, and of apatite. All of these often show a banded structure, not unlike that of the gneiss, to which they are evidently posterior, and of which they

often contain fragments. Their study is full of interest to the geologist.

The mining operations on these great lodes, often over one hundred feet in breadth, are in part by open cuts and in part by shafts, and have reached depths of a little over 200 feet. The production of some three or four of these mines in 1882 was from 4000 to 5000 tons each of commercial apatite. The improved machinery and the better system now in course of introduction here are greatly increasing the yield of these mines, some of which during the past summer have put out 600, 700, and even 1000 tons in a month. The mineral, yielding on an average eighty per cent. of phosphate of lime, is now worth in Montreal eighteen dollars a ton, and is mined with great profit. It is now chiefly shipped to Great Britain, where it is used for the manufacture of high-grade superphosphates; but it is believed that in the near future a larger market will be found for the apatite in the United States and Canada. The growing demand for high fertilizers on this continent, and the fact that the apatite of Canada may be shipped to the valleys of the Ohio and Mississippi much more cheaply than the phosphate rock of South Carolina, give a great importance to these Canadian mines. The output from those of the Lièvre district this year will probably exceed 30,000 tons. Works on a large scale are now in construction at the lower falls of the Lièvre, on the line of the Canadian Pacific Railroad, for the grinding of phosphates and the manufacture of fertilizers.

While the production of the Lièvre mines has caused the neglect of the earlier-discovered deposits of the Rideau district, there are among the latter some which, in my opinion, will be found, when properly developed, not inferior to those of the Lièvre; and I believe that these two districts of phosphate-bearing veins in Canada will soon become an important source of revenue to the country, and a great benefit to the agriculture of the continent.

## Discussion.

R. P. Rothwell, New York City: In this connection I wish to call attention to another Canadian product, destined, I believe, to prove most useful to agriculture. I refer to arsenic, which is manufactured at Deloro, Ontario, in the treatment of auriferous arsenical pyrites. It has been found that arsenic, mixed with the phosphates or scattered directly upon the soil, is a sure destroyer of

all injurious insects and worms, while at the same time it is not taken up by the vegetable growth, and does not prove in any way dangerous to farmer or consumer. Some striking results have already been experimentally obtained by its use; and I hope to be able, when these shall have been verified on a more extended scale, to lay before the Institute the proofs of its great importance. The limited employment of Paris green, principally against the potato-bug, is well-known. But it appears probable that the simple arsenious acid, which is relatively insoluble, will prove not only cheaper and safer, but more efficacious and more generally applicable.

---

## *IMPROVEMENTS IN ORE-CRUSHING MACHINERY.*

BY S. R. KROM, NEW YORK CITY.

In connection with perfecting a system of pneumatic concentration I had in view the improvement of machines for crushing and pulverizing ores. A study of the whole subject convinced me that the principle upon which the construction of the Blake crusher, and that of rolls, is based, possessed the mechanical elements which, if perfected and simplified, would make these machines the successful rivals of every other device. It is well-known that until very recently the stamp-battery held undisputed possession of the field; and mill-men and mill-builders almost universally believed that stamps would not be superseded by any other machine for fine crushing. The first step to drive stamps from the field was the introduction of rollers in the Bertrand and the Mt. Cory mills. In both of these mills the great superiority and economy of a system of crushing with rollers instead of stamps has been fully demonstrated. While perfecting the rollers, I had the fact confronting me that they had frequently been tried without success. In fact, the universal opinion prevailed that rollers could be used only for coarse, and not for fine crushing. The secret of the difficulty I discovered to lie in the imperfect and weak character of the rolls heretofore used, due to a misconception of the requirements for a machine for such work, and *a failure to appreciate the advantages of continuous, rolling, crushing-surfaces, operating on the toggle-lever principle, which gives the greatest crushing pressure with the least power expended, and the minimum of wear.*

But no sooner is the fact established that rolls are destined to supersede stamps, than some jump to the conclusion that cheap rollers will also prove successful; and manufacturers of cheap machines are making statements that they sell rolls at one-half the price of improved steel rolls, which will do the same work. Those who believe such statements and buy such cheap rolls will pay dear for their experience. Great strength, superior material, perfect workmanship and completeness, as well as simplicity, of design, are indispensable to economy and efficiency in practice; and these elements can only be secured by paying a fair price for the machine.

The Blake crusher is so well-known that no description of it is necessary here. During the life of the patent (twenty-one years) of this celebrated and valuable machine, the frame was cast in one piece, and no improvement of any importance was made in the construction until after the patent had expired.

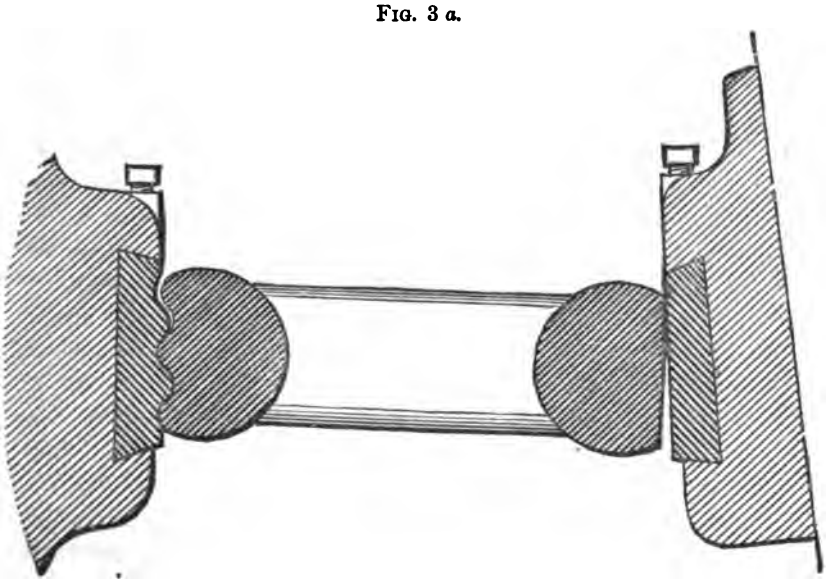
The first practical plan to improve the construction of the Blake crusher is shown in Fig 1, and was patented in 1875. The principal features covered by the patent are the tie-bolts to take the strain due to crushing, and breaking-cups to relieve the machine from excessive strain. The breaking-cups are placed on the tie-bolts and also on the pitman; but it is intended that the small cups on the pitman should be the weakest, and that only these should give way. A lug underneath the pitman holds it from dropping too low. This method of constructing a crusher with bolts not only makes a stronger machine, but one of less weight and easier to transport, and allows the employment of means to prevent the machine from being subjected to undue strain.

The next steps in improvement are shown in Figs. 2 and 3. In this machine the upper tie-bolt is shortened, so as to give a better and more convenient form to the side-frame, and the lower tie-bolt is so placed that it receives all the strain due to crushing the ore. In the toggle-abutment through which the main tie-bolt passes are recesses around the bolt holes, and these recesses are covered with wrought-iron washers of sufficient strength not to bend under the ordinary strain in crushing the ore, but to yield to excessive strain. These washers take the place, and serve the purpose, of the breaking-cups in the first machine, but do not fly to pieces; and therefore both ends of the toggle-block yield evenly together, and the frame of the machine is not liable to be twisted or broken, or have the bolts bent.

The third improvement consists in forming the crushing-faces of bars of steel and in the means of clamping them securely in place. These bars are of good steel, rolled exactly to standard sizes, and cut to proper lengths; and the lower bars are hardened to increase their durability. Provision is made for bringing the jaws closer together, to compensate for wear. Thin strips of metal are also provided to put behind the bars to keep the wearing-faces in line. The bars or crushing-faces can easily be got at by taking the nuts from the bolts, and sliding the stationary jaw forward.

The fourth improvement consists in hanging the jaws on an axis below the crushing-faces, instead of at the top, as in the Blake crusher. This manner of hanging the movable jaw gives a more uniform product, and the principle is correct, since the strain on the jaw is greater at the bottom than at the top, and the motion should be the least where the strain is the greatest.

FIG. 3 *a*.



Rolling Toggles.

The fifth improvement consists in the employment of toggles with rolling ends which work without friction or oil. It is shown in Figs. 3 and 3 *a*. In the latter cut, the teeth which hold the toggles in place are omitted on one end so as to better show the rolling-surfaces. The bearings are self-adjusting, large and long, and the machine is constructed for high speed, hard work, and large crushing-capacity.

Fig. 4 represents the first step in the improvement of crushing-rolls, constructed with bolts to take the strain. It is also the first crushing machine with forged steel tires. The system of the gearing is also new. It will be observed also that the pillow-blocks are well adapted to take the strain. This is the first machine of the kind carried on a bed-plate in one piece. Breaking-cups are also introduced to relieve the machine from undue strain. The patent covers the bolts to take the strain, the system of gearing, the manner of putting on the steel tires and the breaking-cups

Some details omitted from Fig. 4 as not essential, are shown in the following figures.

The next step in the improvement of crushing-rolls is shown in Figs. 5 and 6. It consists in a reconstruction of the pillow-blocks so as to adapt them to one bolt on each side instead of two as in Fig. 4. This both simplifies the machine, and in other respects makes a better pillow-block. The bolts being placed close to the bearings serve the purpose better than four bolts, two bolts being much more convenient for adjusting the rolls. This arrangement also allows the shafts to be lifted out of their bearing for repairs without removing any of the tie-bolts, and permits the use of springs on the tie-bolts, as shown at S, Fig. 5. It is not practicable to use springs with four bolts. These springs were introduced to supersede the breaking-cups in Fig. 4. The tie-bolts have solid collars near the middle and a nut on each end. The springs and pillow-blocks are placed between the collar and nut, so that the pressure is obtained without forcing the rolls together, when the springs are set up to give the necessary resistance to crush the ore. At the date of this machine it was considered necessary to employ some means to relieve the machine from undue strain; and the springs as here shown are the best arrangement for the purpose yet devised. The arrangement of the gearing is the same as in Fig. 4, except that the intermediate gear $D^1$ is increased in size, and so placed as to require no change of position when the pillow-blocks are moved up to adjust the distance of the rolls and to compensate for wear. The wheel $D^1$ is placed nearly on a line drawn vertically through wheel $B^2$, but two inches in front of it; and when the tires are worn-out, the wheel $D^1$ will be two inches in the rear of the perpendicular line through wheel $B^2$. This movement of four inches only slightly affects the meshing of the teeth of the wheels $D^1$ and $B^2$, the variation being only $\frac{1}{32}$ of an inch from a true pitch. It will be seen that one roll is driven through the intermediate wheel $D^1$, and the

other by a pinion $C^1$ directly engaging with wheel $B^1$. By this arrangement and location of wheel $D^1$ the rolls can be adjusted without change of position of any of the gear.

In the machine shown in Fig. 4, it was necessary to adjust gear-wheel $D^1$ as the gear-wheel $B^2$ was moved forward towards gear-wheel $B^1$.

The rolls shown in Figs. 5 and 6 were successfully used at the Galena mill, Nevada, and this led to the adoption of an improved form at the Bertrand mill, as described below.

Figs. 7 and 8 illustrate very important additional improvements in crushing-rolls. The first is the substitution of band-wheels for toothed gearing; the second, the substantial casing for inclosing the rolls, and a hopper to insure the spreading of the ore evenly across the face of the rolls. These improvements complete the adaptation of rolls for pulverizing ores to any degree of fineness required. With pulleys we can run at any speed desired and thereby increase the capacity of the rolls. The wear is reduced nearly to the crushing-faces alone; the danger of breaking the machine is avoided; and the rolls perform their work with but little noise and shock.

The housing (Fig. 9) so incloses the rolls that the dust made in crushing is easily prevented from escaping into the building by means of a small draft of air produced by an exhaust-fan. The housing also forms a very substantial frame for supporting the cheek-piece and the feeding-hopper. I prefer to drive with one large pulley, and use the small one to insure the bite of the rolls upon the ore. Both rolls, of course, when crushing, travel at the same surface-speed; but I prefer to speed them so that the roll driven by the small pulley, when the machine is not crushing, will revolve one or two revolutions faster per minute. The reasons for preferring this system of driving with only one large pulley, are:

1. It would not be a good arrangement to hang on the movable pillow-block so large and heavy a pulley as would be required.

2. The driving of one roll will cause the other to revolve at the same surface-speed, where hard ore is fed between them, and therefore it is only necessary to drive one roll with a strong and steady power, and the other with sufficient force to insure the rolls always taking hold of the ore, and to keep them in motion during the time when no ore is between them.

Concerning the machine shown in Figs. 7, 8, and 9, Mr. Albert Arents, Superintendent of the Mt. Cory mill, says, "Now as to the economical question—the only one of practical interest—I will state

that the cost of treating a ton of ore at the Bertrand mill is thirty per cent. cheaper than at the Northern Belle mill [a stamp-mill], although the latter is crowded to its utmost capacity, and treats more ore than any other mill of its size I know of . . . . . I once advised having a side-motion to one of the rollers; but I find if they are fed evenly the rollers wear even. I am astonished at the even degree of wear of the steel tires. I would not use stamps now for our purpose under any considerations."

Mr. R. S. Clark, Superintendent of the Bertrand Mining Co., says: "One great reason of our cheap milling at the Bertrand is that we use rolls instead of stamps. We crushed about 15,000 tons of ore before putting new tires on the finishing rolls, and have crushed in all about 20,000 tons; and we do not expect to put new tires on the roughing rolls for two or three months yet. From my experience of the past fourteen months, it is safe to calculate that each set of tires and each set of phosphor-bronze linings will last to crush 20,000 tons of ore. There has been no other expense for repairs upon our rollers except the cheek-piece. The faces of the worn-out tires are not grooved at all, and they would be still good for wear had they not expanded by becoming worn thin. They have certainly stood the test of time and are to-day more in favor with us than ever before. We would not have stamps if furnished without cost, and kept in repair for nothing also."

The next and latest step in the improvement of crushing-rolls is the swinging pillow-block, shown in Figs. 10 and 11. This, by reason of its uniqueness and importance, deserves to rank first in the order of merit. In all other machines, one pair of the pillow-blocks is arranged to slide on the bed-plate, and each one of the sliding pillow-blocks has to be adjusted separately. It requires care to bring up the two movable pillow-blocks evenly and parallel with the stationary ones; and any looseness between the faces of the movable pillow-blocks and the bed-plate results in damage to the faces and pounding on the bed. In this machine all the bearings are securely and firmly fixed to the bed-plate, and no chance whatever exists for looseness, causing wear or damage to any part of the machine. In fact, the movable bearings are now better secured to the bed-plate than the stationary ones, although the latter are very securely bolted on the bed. The two swinging bearings are united together by a very heavy shaft (*m*, Fig. 11) 11 inches in diameter, so that the bearings must swing together, and consequently the rollers and shafts are always parallel. The shaft *m*, connecting the swinging

bearings, is so strong that one bolt on one side is sufficient to hold the rolls together when crushing ore. It will be observed that springs have been dispensed with. The machine is constructed so strong that they are no longer required; and besides, I now employ magnets to take out from the ore all pieces of steel which might dent the faces of the rollers.

The rolls work better and more economically without springs. Contrary to what might at first be expected, the machine is more simple than any other and more durable. The tires are held by two heads slightly cone-shaped. One of these heads is securely fixed to the shaft by shrinking it on. The other is split on one side, so that when the heads are drawn together by the bolts, within the tires, the split head will close tightly upon the shaft.

Recapitulating the several improvements described, we have:

1. Steel tires and the method of securing them.
2. Pulley-gearing.
3. Housing to inclose the rollers.
4. Swinging pillow-blocks.
5. Bolts to take the crushing strain.
6. The hopper for spreading the ore.

This paper would not be complete without a comparison between rolls and stamps (other pulverizing machines not being worthy of attention here). On this head I submit the following observations:

1. The capacity of any machine for crushing ore is dependent on the amount of crushing-surface brought in contact with the ore in a given time, and the efficiency with which the crushing-surface is applied.

2. The cost of crushing depends on the power consumed and the expense of maintaining the machine in a working condition.

It will be manifest from these axioms that the employment of correct mechanical principles with simplicity of construction and fewness of working parts will play an important part in the settlement of the question. For this calculation we will begin by computing the capacity of two sets of 26-inch rolls with 15-inch face, the average diameter of which by reason of wear will be say 24 inches. One pair of the rolls is to receive the coarsely crushed ore from the breakers and the other set is for finishing or pulverizing. Such rolls, running 100 revolutions per minute, will bring into contact with the ore 113,100 square inches, and the two sets of rollers are therefore equal to 226,200 square inches of effective crushing surface per minute.

The usual diameter of each stamp-shoe and die is 8 inches, and the area is therefore 50 square inches to each stamp. *Counting all this as effective crushing surface*, we have for each stamp (falling, say 90 drops per minute) 4500 square inches of crushing surface. It will therefore require 50 stamps to give nearly the same surface (namely, 225,000 square inches) as can be obtained with two sets of 26-inch rollers.

Let us now consider the two machines from a purely mechanical point of view. Stamps crush by the percussive effects of a falling weight, and the power consumed is in excess of the work performed; because it takes the same power to operate stamps, whether the blows are effective or not, and it is safe to assume that one-half the power is lost. With rollers the crushing force is applied continuously in one direction, and, other things being equal, it must be evident that the power is far more economically utilized. Fig. 12 illustrates the difference, representing the faces of the rolls as composed of the shoes of a stamp-battery and the stamp-heads, stems, and tappets as fastened to, or composing the fly-wheel, to give weight and steadiness of motion and crushing force sufficient to overcome irregularities of resistance. It must be evident that if the rolls, Fig. 12, are held sufficiently rigid together, the pieces of rock falling between them will be crushed and the power consumed will be in proportion to the work done, while the surplus power will be stored up in the fly-wheel. If the same amount of metal were put in stamps, on the other hand, and the stamps did not (as of course they would not) give in falling a full equivalent of useful work for the power consumed in raising them, the excess of power is wasted with no possibility of recovery. Moreover, the blow of a stamp has no regular efficiency, and is always only partially effective by reason of crushing on too much ore or on ore already fine enough.

With rolls the crushing-effect is positive, and ore cannot pass between them without being crushed if they are properly held together. Besides, no ore which is fine enough is acted upon a second time. Again, the toggle-lever principle acting in rolls, as illustrated in Fig. 13, serves to give the necessary crushing-pressure with the smallest expenditure of power, while with stamps the contrary is the case.

I have met persons who have claimed that the percussive effect of a blow has some quality more effective than pressure. Now the velocity which the stamps attain at the moment of striking the ore, dropping 9 inches, is 7 feet per second, while the surface of rolls 24 inches in diameter, running 100 revolutions per minute, travels

628 feet per minute, or about 10½ feet per second. This gives already more percussive effect than stamps; so that, if percussion is any aid to pulverizing, we have it in the rolls also by giving them velocity. But I do not adopt this reasoning. The whole matter is summed up in the statement, that stamps *must* attain a certain velocity to crush, while the crushing-effect of rolls is produced at either high or low velocity, without material change in quality of product; speed, however, giving increased capacity.

Simplicity of construction has also been claimed for the stamp-battery. Let us see if this claim can be sustained.

The working or wearing parts of each set of two rolls, as above illustrated, are as follows:

4 journals on two shafts.
4 pillow-blocks for journals.
2 crushing-rollers.
2 side wearing-plates.

Total: 12 wearing-parts to each set of rolls, or 24 in two machines. None of these parts can break, or are subject to rapid wear.

On the other hand, the working or wearing parts in a 50-stamp battery are:

15 journals on 5 shafts (viz., 10 stamps on each shaft).
5 cam-shafts.
15 bearing-boxes for journals.
50 stems.
100 guide-boxes for stems.
50 stamp-heads (bosses).
50 shoes.
50 dies.
50 cams with keys.
50 tappets with keys.

Total: 435 parts, all of which are subject to severe wear or liable to break.

Recapitulating our comparison:

1. The average crushing surface of 26-inch rolls is 226,200 square inches, while the crushing surface of 50 stamps is only 225,000 square inches per minute.

2. Two sets of rolls have only 24 wearing parts, while a 50-stamp battery has 435 wearing parts (to say nothing about the screens, which are frequently damaged, and the meshes of which become clogged with ore).

3. The breakage and wear of stamps are much greater than those of rolls.

4. The rotary crushing motion of rolls, mechanically considered, is better and more economical than crushing under falling weight, or with any other machine or system.

5. By the toggle-lever principle in rolls, advantage is taken of the most economical and powerful means of obtaining the necessary crushing-pressure on the ore, which cannot be obtained in any other way, and is not obtained in any other machine.

Mr. C. A. Stetefeldt, in an appendix to his able paper on *Russell's Improved Process for the Lixiviation of Silver Ores*,* has made a comparison between steel rolls and stamps, to which I need add nothing, except to corroborate and emphasize it from later data of experience. I may point out one advantage of rolls which Mr. Stetefeldt does not mention, viz., their freedom from the terrible noise, dust, and frequent stoppage for one cause or another, to which stamps are liable.

Since Mr. Stetefeldt's paper was written, the capacity of the rolls in the Bertrand mill has been rated at 150 tons per twenty-four hours, crushing to pass a 16-mesh screen. This is 50 per cent. more than Mr. Stetefeldt felt justified in assuming. The rolls have also been put in successful operation in the Mt. Cory mill, Nevada, and the Haile mill, South Carolina.

What the full capacity of the improved rolls is, has not yet been demonstrated by actual test, as either the screening or elevator capacity has not been sufficient to allow a complete demonstration of this point. We only know that at the Bertrand mill the rolls crushed 50 tons of hard ore in twelve hours, and in the Mt. Cory mill, 50 tons to 30-mesh fineness in the same time. If we rate the capacity of stamps of 850 pounds at 2 tons per stamp in twenty-four hours, doing the same kind of work, this would show that two sets of 26-inch rolls are equal to 50 stamps. The calculation given in the preceding pages, and results in practice, justify, I think, this rating.

Mr. Clark of the Bertrand Company says: "We have demonstrated the following facts: That we can pulp more ore with the rollers than can be done with a 40-stamp battery; that we have crushed 9000 tons of ore without a dollar's expense in repairs; that we have done it with less than one-half the power that would have

* *Transactions*, vol. xiii., p. 114.

been required had we used stamps; that the cost of repairs, wear, and tear will not exceed one-quarter of that of crushing with stamps; that we make less dust, jar, and noise."

At a later date Mr. Clark says: "We crushed 15,000 tons of ore before putting new tires on the fine-crushing rollers, and have crushed now 20,000 tons; and it will be two or three months yet before we will put new tires on the coarse-crushing rollers. It will be safe to calculate that each set of tires with a set of composition liners for journals will last to crush 20,000 tons of ore. There has been no other expense for repairs upon our rollers except the cheek-piece."

On the above basis (crushing 20,000 tons with a wear of two sets of steel tires and one set of composition liners) the cost of renewal at present prices for steel will be as follows:

| | |
|---|---|
| Two sets of steel tires, | $530 00 |
| Freight on 3264 pounds, at 3 cents, | 98 00 |
| Composition liners for journals and cheek-piece, | 100 00 |
| Total, | $728 00 |

which amounts to $3\frac{6}{10}$ cents per ton of ore.

But after all that has been proved for rolls, it is still sometimes asserted that they are only suitable for coarse crushing; that ore cannot be pulverized with them sufficiently fine for amalgamation and other purposes where pulverizing is needed, such as cement, phosphate-rock, etc. This is true, as before pointed out, of ordinary cheap rollers only. The same assertion was made when it was proposed to adopt rolls in the Bertrand mill for pulverizing ore for lixiviation; and almost everybody who knew of the affair predicted that the rolls would prove a failure. At the same time, such critics admit that stamp-batteries, centrifugal roller-mills, attrition-mills, ball-pulverizers, mill-stones, and various unpractical machines will pulverize. It would be as good reasoning to argue that a heavy load can be drawn on a sleigh on bare ground, but that the same heavy load cannot be carried on a strong and well-constructed wagon or railroad car. *Crushing with rolls is carrying the load on wheels, while all the other devices are similar to dragging the load with great loss of energy.*

Rolls as a pulverizing machine, if properly constructed, cannot be improved upon either in principle of operation or in economy of results. All the parts are of such a character as to contribute to

their durability, and there is *no limit* to proportioning the journals so as to fit them to carry any load that may be put upon them. The capacity of rolls for quantity and hard work is far greater than that of any other existing device.

Rolls are at last receiving the recognition they deserve as a pulverizing machine. It is now proposed to employ rolls to crush fine after the ore has passed the stamp-battery, so as to increase the capacity of an existing plant—which is a complete reversal of all former ideas on the subject. Yet I have sold rolls for this purpose. Considering the subject from a mechanical standpoint, it is astonishing that rolls were not brought to perfection and widely adopted long ago.

---

## *THE MANUFACTURE OF IRON IN CANADA.*

BY JAMES HERBERT BARTLETT, MONTREAL, CANADA.

### I.

### The Manufacture of Iron in the Province of Quebec.

*The St. Maurice Forges.*—The deposits of iron-ore in the St. Maurice district, in the rear of Three Rivers, were probably known to the Indians and Jesuits, but it is not till 1667 that any discovery is reported. The affairs of the colony were then in the control of the "West India Company," who amongst other monopolies had a right to all mines and minerals.* Specimens of the iron-ore were examined in Quebec in 1668 by the Sieur la Potardière, who reported unfavorably on them.

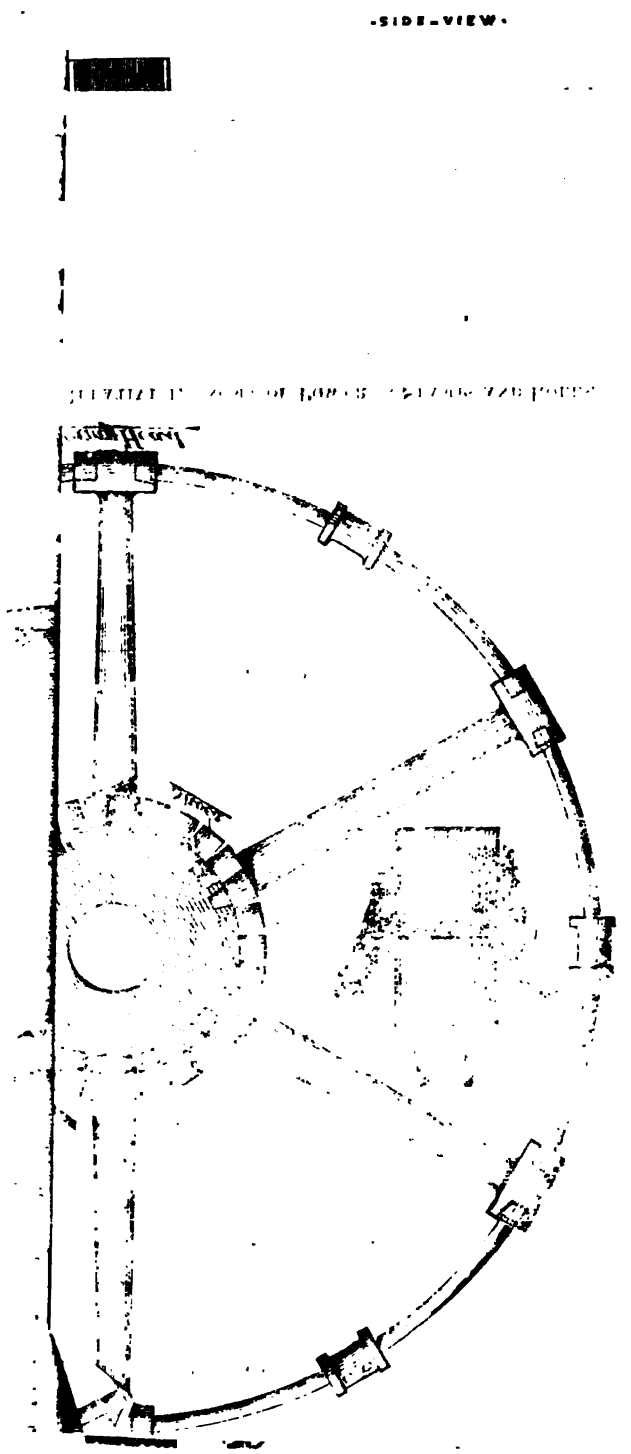
In 1671, Louis de Buade, Comte de Frontenac, was appointed governor of La Nouvelle France; and in the original manuscripts relating to his administration some allusion is occasionally found to the St. Maurice iron mines.† In a letter to the Imperial Government, dated 2d November, 1672, he says:

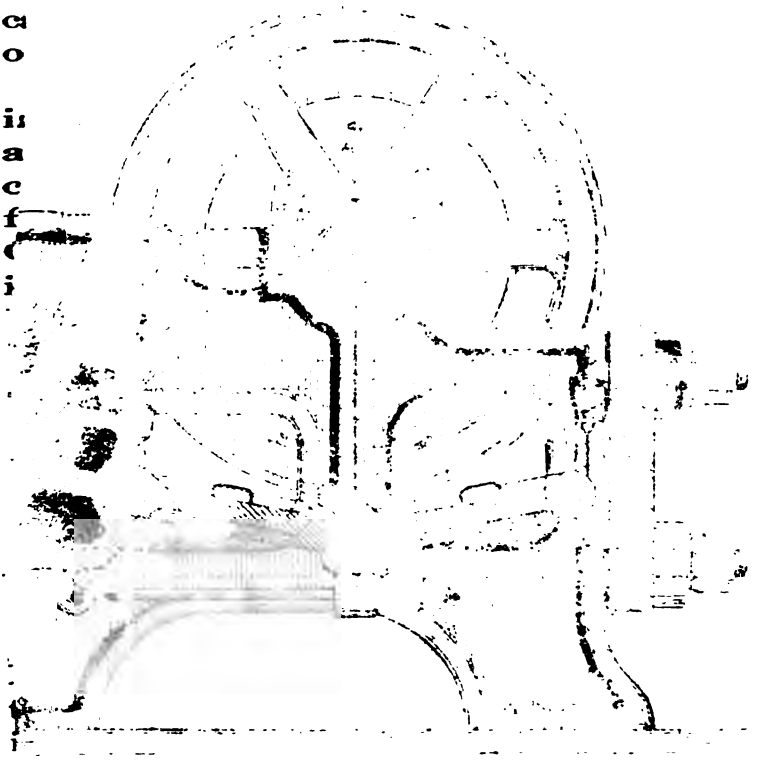
"The iron mine of which I have already spoken is of great consequence. I have visited it myself, in order that I may be enabled to give a more accurate account of its nature. I am gratified to learn that another mine has been discovered in Champlain, which is much richer than the Cap de la Madelaine mine, and the ore is in greater

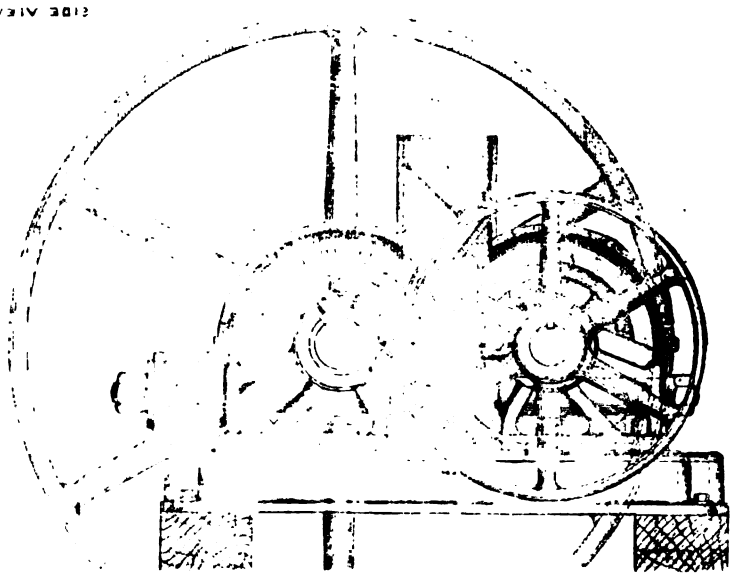
---

* Smith's *Canada*, 1851, vol. 1, p. xlvii.

† *British and Canadian Review*, by Macaulay.


-SIDE-VIEW-





abundance. I apprehend that it will be next to impossible to exhaust this mine, as there is an extent of country of four leagues in length from Cap de la Madelaine to Champlain, which is covered with iron-ore; all the streams indicate its existence. I had the curiosity to taste the water, and I found it all strongly impregnated with rust and iron, but the miners whom I sent there render the affair certain; they are now working there and if you have any intention of establishing forges and a foundry, you may be certain that the material will not be wanting. There are six piles of ore, now lying at Cap de la Madelaine which, according to the annexed report of the miner, would last for two castings a day for four months. The important question is the placing of the forges. According to my opinion I should prefer building them on Ruisseau Pepin, which is in Champlain, rather than at the Cape, where the Jesuit fathers have a mill already in operation. By thus placing the forges they would be between the two mines, and the material could be more easily conveyed from both to the central establishment. When you have decided upon establishing the said forges, as the workmen you will send out will be competent men, they perhaps can decide whether there is enough water in the stream I have above mentioned to work the wheel of the projected forges, also to judge whether it would not be practicable to bring in other streams in the neighborhood, such as Ruisseau d'Hertel, to increase the quantity of water. The chief miner, who is now here, assures me that this can be easily and successfully done. It is certain that if the forges are once established many advantages will result to the colony; excellent iron will be manfactured there, and the consumption of fuel will help materially in the clearing of the forest land. Moreover, many men will be employed at the work, and a market will thus be afforded for the surplus provisions which we have at our disposal."

The West India Company surrendered its charter in 1675, and on the 4th of August, 1676, the first deed in connection with the forges appears, as the original concession of the Seigneurie of St. Maurice was made on that date to Dame Jeanne Jalope, widow of Maurice Poulin, Sieur de la Fontaine, King's Attorney for Three Rivers, by the Intendant, M. Talon.

On the 19th January, 1683, Dame Jalope gave the property to her son, Michel Poulin; but the other children evidently had some claims upon it, as on the 30th of April, 1683, there is a discharge recorded from Jean Baptiste Poulin de Corval, one of the brothers, and on

the 20th November, 1690, a discharge was registered from François le Maitre de la Movill, who married a sister.

In 1681, an extract from a letter, by the Count de Frontenac, reads as follows:

"I am convinced that there is a very fine iron-mine in the vicinity of Three Rivers, where a forge could be profitably worked. I wish I had a man here who could plan the construction of an establishment of that kind; it would be of great use to His Majesty the King and to the whole colony. Monsieur Vallon can inform you, my lord, how Mons. de Colbert has tested the quality of the ore and with favorable results. I have sent a small quantity to Mons. Arnoul, who can give you an account of it. There is a large stream in the vicinity of this mine."

In 1685 the Marquis of Denonville was appointed governor, and on the 18th of November, the following year, in a despatch to the government of France, he says:

"I have this year again had the iron-mine near Three Rivers thoroughly examined. I am convinced that there is a much larger quantity of that metal than the colony requires. The great desideratum is the discovery of a stream or water-power, which can be used in winter, and it is in this respect that we require an able experienced man, who could see what could be done for the establishment. Last year I sent a sample of this iron to France, and the iron-workers, who found it of good quality and percentage, wish to have fifteen or twenty bariques to give it a thorough trial as to quality; it would be well to satisfy them on this point next year. If our Northern Company should succeed there would be no difficulty in accomplishing this desirable object."

On the 4th of April, 1725, Pierre Poulin made "Foi et Hommage"* in the castle of St. Louis in Quebec for himself, and also on his brother's account, for the *fief* and *seigneurie* of St. Maurice, and on the following day "L'aveu and Denombrement" of the seigneurie was made.

The mining rights and minerals do not seem to have been granted with the land; for King Louis XIV., on March 22d, 1730, granted a license to a M. Francheville to work the mines, and a partnership was entered into by him with Peter Poulin, Gamelin and Cugnet, for this purpose, the deed of partnership being dated the 16th of June, 1733. It seems probable that a forge was now built, but the enter-

* See Parkman's *Old Regime*, p. 246, also Lemoine's *Quebec Past and Present*, p. 121, for a description of "Foi et Hommage."

prise did not prove a success; the principal, Francheville, having died, his widow and the other partners, on the 23d of October, 1735, surrendered their rights to the Crown.

The iron-ore was a bog-ore, the deposits being on the surface, or only a few inches below the soil, so that the work of collecting the ore was more digging than mining, and it was necessary to have access to a considerable area of land. We find that on the 15th of October, 1736, Poulin, Louise de Boulanger his wife, and Michel Poulin his brother, a priest, sold the *fief* and *seigneurie* St. Maurice, to François Etienne Cugnet, Pierre François Taschereau, Olivier de Vezain, Jacques Simonet, and Ignace Gamelin for 6,000 livres, with no terms, so long as they paid 300 livres a year.

The partners above named were called Cugnet & Cie., or "La Compagnie des Forges," and the King of France, now Louis XV., by an order-in-council dated April 22d, 1737, empowered them to erect iron-works, and for this purpose advanced them 100,000 livres and claimed no rents or dues. They accordingly in that year built a blast furnace, and on the 12th of September obtained a concession of some more land, called the *fief* St. Etienne, from M. Hocquart, who was Intendant at that time. In two years' time, a French artisan was procured who improved the works and methods of working; but it was all in vain, a want of capital being said to have been the cause of failure. The Company could not carry on the works, but had to give them up, and, on the 1st of May, 1743, the Crown took possession, whereon they were worked on the King's account and in his name.

"Skilled workmen were sent out from France, who rebuilt, in part at least, the blast-furnace as it now stands, and erected a Walloon hearth which is still in use for refining."* Extensions and additions were made, and the place in six years' time had assumed very considerable proportions, as the following account will show.

On August 3d, 1749, Professor Peter Kalm, Professor of Economy in the University of Aobo in Swedish Finland, and member of the Swedish Royal Academy of Sciences, stopped at Three Rivers in his travels through the country, for the special purpose of seeing the iron-works. He thus describes his visit:†

"Whilst my company was resting, I went on horseback to view the iron-works. The country which I passed through was pretty

* Dr. T. Sterry Hunt, in Swank's *Iron in all Ages*, 1884.

† *Travels into North America*, by Peter Kalm, London, 1771, vol. iii., p. 87.

high, sandy and generally flat. I saw neither stones nor mountains here. The iron-work, which is the only one in this country, lies three miles to the west of Trois Rivières. Here are two great forges, besides two lesser ones to each of the great ones and under the same roof with them. The bellows were made of wood, and everything else, as it is in Swedish forges. The melting-ovens stand close to the forges and are the same as ours. The ore is got two French miles and a half from the iron-works and is carried thither on sledges. It is a kind of moor-ore, which lies in veins within six inches or a foot from the surface of the ground. Each vein is from six to eighteen inches deep, and below is a white sand. The veins are surrounded with this sand on both sides, and covered on the top with a thin mould. The ore is pretty rich and lies in loose lumps in the veins, of the size of two fists, though there are a few which are near eighteen inches thick. These lumps are full of holes which are full of ochre. The ore is so soft that it may be crushed betwixt the fingers. They make use of a gray limestone which is broke in the neighborhood for promoting the fusibility of the ore; to this purpose they likewise employ a clay marl, which is found near this place. Charcoals are to be had in great abundance here, because all the country round this place is covered with woods, which have never been stirred. The charcoal from evergreen trees, that is, from the fir kind, are best for the forge, but those of deciduous trees are best for the smelting-oven. The iron which is here made is described to me as soft, pliable and tough, and is said to have the quality of not being attacked by rust so easily as other iron; and in this point there appears a great difference between the Spanish iron and this in ship-building. This iron-work was first founded in 1737 by private persons, who afterwards ceded it to the King; they cast cannons and mortars here of different sizes, iron stoves which are in use all over Canada, kettles, etc., not to mention the bars which are made here. They have likewise tried to make steel here, but cannot bring it to any great perfection, because they are unaquainted with the best manner of preparing it. Here are many officers and overseers, who have very good houses built on purpose for them. It is agreed on all hands that the revenues of the iron-work do not pay the expenses, which the King must every year be at in maintaining it. They lay the fault on the bad state of population, and say that the few inhabitants in the country have enough to do with agriculture, and that it therefore costs great trouble and large sums to get a sufficient number of workmen. But, however plausible this may

appear, yet it is surprising that the King should be a loser in carrying on this work, for the ore is easily broken, very near the iron-work and very fusible. The iron is good and can be very conveniently dispersed over the country. This is, moreover, the only iron-work in the country, from which everybody must supply himself with iron tools, and what other iron he wants. But the officers and servants belonging to the iron-work appear to be in very affluent circumstances. A river runs down from the iron-work into the river St. Lawrence by which all the iron can be sent in boats through the country at a low rate. In the evening I returned again to Trois Rivières."

There evidently was very good ground for Kalm's suspicions, as the peculations of the Governor, Intendant, and principal officials were at this time notorious, and "complaint after complaint was despatched to France touching the ruinous state of things they were fast producing in the Province."*

The Governor, the Marquis de la Jonquière, was recalled, but died in Quebec, in May, 1752. In that year an inspector, M. Franquet, was sent to visit the different posts in La Nouvelle France, and the following is a translation of a portion of a French manuscript account of his visit to the forges:†

"M. Bigot, Intendant of New France, who resides at Quebec, had recommended me to visit the St. Maurice forges, as the establishment was extensive, and as he had no doubt that I would be pleased to be in a position to give an account of it. By stopping at Three Rivers, I could reach the forges in two hours, so having settled upon that course, I requested M. Rigaud, who was then in charge of that post, to accompany me. We left Three Rivers at 5 o'clock A.M., with M. Tonnancour and other friends, whom M. Rouville, director of the forges, had invited to accompany us. In leaving the town, we ascended a hill covered with sand, crossed a plain, and passed through a wood of stunted trees, on emerging from which we stood on a hill overlooking a valley, in which the said forges of the king are situated; we crossed a wooden bridge built over a small stream, and disembarked from our conveyance at the door of the Director's dwelling. After the first ceremony of reception by the Director, his wife, and the other employés, we proceeded to visit the works. The stream which drives the machinery is dammed up in three places; the first dam drives the wheel for the

* McMullin's *Canada*, 1855, p. 106.

† Macaulay in *British and Canadian Review.*

furnace, the second and third each a trip-hammer. Each dam has a water-pass to prevent overflow in high water; it is supposed that the stream or water-power is sufficiently strong to drive two other hammers. The buildings of the post are irregularly situated on the banks of a stream, and little or no taste seems to have been displayed in placing them. The principal building is the Director's residence, a very large establishment, but scarcely large enough for the number of employés who have to be accommodated.

"On entering the forge, I was received with a customary ceremony; the workmen moulded a pig of iron about 15 feet long, for my special benefit. The process is very simple, it is done by plunging a large ladle into the liquid boiling ore and emptying the material into a gutter made in the sand. After this ceremony I was shown the process of stove-moulding, which is a very simple affair, but rather an intricate operation; each stove is in six pieces, which are separately moulded, they are (afterwards) fitted into each other, and form a stove above three feet high. I then visited the shed where the workmen were moulding pots, kettles, and other hollow-ware. On leaving this part of the forge we were taken to the hammer forges, where bar iron of every kind is hammered out. In each department of the forges, the workmen observed the old ceremony of brushing a stranger's boots; in return they expect some money to buy liquor to drink to the visitor's health. This establishment is very extensive, employing upwards of 180 men. Nothing is consumed in the furnace but charcoal, which is made in the immediate vicinity of the post. The ore is rich, good, and tolerably clean; it formerly was found on the spot, now the Director has to send some distance for it. The management of these forges is economical. It must be readily understood, that owing to the numerous branches in which expenditure must be incurred, unless a competent man be at the head of affairs, many abuses would be the consequence. Among other employés, His Majesty the King supports a Recollet Father at this establishment, with the title of Aumonier. This iron is preferred to the Spanish iron, and is sold off at the King's stores in Quebec at the rate of from 25 to 30 castors (beaver skins) per hundred weight. In order to obtain a better knowledge of the position of these works, I would refer to the notes sent to the Court of France on this subject, wherein will be found all details of their management. I may say, however, in conclusion, that they are unprofitable to the King, and I am assured that if they were offered on lease at public sale, one hundred pistoles per annum might be pro-

cured for them. After a splendid dinner at M. de Rouville's mansion, we returned to Three Rivers highly pleased with our visit, and took supper at M. de Tonnancour's. The distance from the town to the forges is nine miles."*

It would appear as if the forges produced more iron than the colony could consume, and that, although some was exported to France, the authorities there would not be convinced that it was fit for firearms; so it was proposed to form a naval establishment in Canada and make use of this Canadian iron in shipbuilding. Orders were accordingly given for erecting docks at Quebec for building men-of-war, but nothing was in effect accomplished.†

We next hear of these forges in the articles of capitulation between their Excellencies Major-General Amherst, Commander-in-chief of His Britannic Majesty's troops and forces in North America, on the one part, and the Marquis de Vaudreuil, etc., Governor and Lieutenant-Governor for the King in Canada, on the other, on the 8th of September, 1760.

Article XLIV. says: "The papers of the Intendancy, of the officers of Comptroller of the Marine, of the ancient and new treasurers of the King's magazines, of the officers of the revenue, and *forges of St. Maurice*, shall remain in the power of M. Bigot, the Intendant, and shall be embarked for France in the same vessel with him; these papers shall not be examined."

The Intendant arrived safely in France, but was at once seized and imprisoned, and made to disgorge most of his ill-gotten gains.‡ The forges and all pertaining to them now passed into the hands of the British Crown, and, although for some years there are no records, there is no doubt that they were worked.

In 1767 the Crown, which was represented at that time by Governor Murray, leased the tract of land and works for sixteen years from the 19th of June, to Christophe Pellisier, Alexandre Dumas, Thomas Dunn, Benjamin Price, Colin Drummond, Dumas St. Martin, George Alsopp, James Johnson, and Brook Watson, at a rental of £25 currency per annum. In 1775 the American invasion occurred, when it appears that Pellisier helped the invaders with both goods and money, and went to see them at Holland House,

* Taken from the *British and Canadian Review*, vol. i., No. 2, January, 1863, by M. Macaulay.

† *History of America*, by William Russell, of Gray's Inn, London, 1778, Book iv., p. 372.

‡ Parkman's *Montcalm and Wolfe*.

near Quebec; he also cast shot and shell for them to be used in the siege of Quebec, and finally, the night before the battle of Point du Lac, where the invaders were beaten by the English under General Carlton, he ran off to Sorel and the United States, taking with him all the funds, as also the vouchers for the money advanced to the Americans, about £2000, got them cashed, and sailed for France. This crippled the company, but, by dint of hard work, they managed to recover and continued operations till the expiration of their lease.*

On the 10th June, 1783, Conrad Gugy was the new lessee, and his term was for sixteen years at £18 15 sterling per year. He sold the balance of his lease on the 10th of March, 1787, to Alexander Davidson and John Lees for the sum of £2300 currency. This partnership was subsequently dissolved, as on the 6th of June, 1793, Alexander Davidson sold the balance of his lease to George Davidson, David Munro, and Matthew Bell for £1500 currency. Their term expired in 1799, but, on the 30th of May in that year, they were granted an extension to the 1st April, 1801, at the same rental.

A new arrangement was now made, Munro & Bell entering into a five years lease and paying an annual rental of £850 sterling. This lapsed in 1806, but they continued to hold it on sufferance till the 1st of January, 1810, when they secured a lease for twenty-one years, at £500 per annum.

At this time the manufacture of iron was the most important industry in Canada,† there existing then a considerable export of cast-iron articles, particularly of stoves.

From year to year the place had grown. The following account gives an idea of what it was: "The establishment is furnished with every convenience necessary to an extensive concern, the furnaces, the forges, the founderies, workshops, etc., with houses and other buildings, present the appearance of a tolerably sized village. The principal articles manufactured are stoves of all kinds used in the Province, large potash kettles, machines for mills, and various kinds of cast and wrought iron, also a great quantity of pig and bar iron for exportation. The number of men employed is from 250 to 300. The overseers and persons employed in the construction of models are English and Scotch, the workmen are generally Canadians."‡

The inhabitants in the District now began to complain that so

---

* F. C. Wurtele.

† *Letters from Canada*, Hugh Gray, London, 1809, p. 22.

‡ Bouchette's *Lower Canada*, 1832. St. Maurice.

much land was leased to the forges that "the town of Three Rivers was hemmed in at the back," and that people who desired to settle in that neighborhood could not obtain any land; this irritation was further increased, "by a proclamation the lessees induced Lord Dalhousie (Governor from 1820 to 1828) to issue, prohibiting even the making of maple-sugar on the land in question. This had been an immemorial source of advantage to the inhabitants around; in the season from 300,000 to 500,000 pounds were made each year. Even the pretence of destruction to the fuel could not be made for this, as tapping the trees did not destroy them for wood."

The Honorable Matthew Bell, Seigneur of St. Maurice, was a man of great importance; he lived in princely style in his chateau at the forges, where he kept a stud of horses and a pack of fox-hounds, and when his lease expired on the 31st of March, 1831, he was able to get it renewed by orders-in-council from year to year till 1846. He died shortly afterwards, and at the time of his death was in very reduced circumstances, being insolvent before he gave up the forges.

The Crown now resolved to sell the property, and it was bought at auction by Henry Stuart, Advocate of Montreal, on August 4th, 1846, and was leased by him to James Ferrier, of Montreal, who worked it for some years.* Henry Stuart finally sold his interest to Andrew Stuart and John Porter, of Quebec, who abandoned it in 1859, as it did not pay.

It appears that when Henry Stuart purchased the property he paid very little, if anything, on it, and the balance of the purchase-money not being paid when due, the Crown obtained a judgment against him and seized the property, which was sold by the sheriff on the 22d October, 1861. "The forges not bringing the value set upon them by the Crown were acquired by them for $7200,"† and sold (together with a farm attached, but without any more land) the following year to Monsieur Heroux, of St. Barnabé, for $7000, who in his turn sold the forges, retaining the farm, to John McDougall, for £1700 currency. This price included the furnaces, works, house, cottages, water-privileges, etc. All the land formerly pertaining to the forges was sold to the squatters and settlers who supplied ore and wood to the works, which were now once more resumed. Their

* The Hon. James Ferrier informs me that he occupied and worked the forges for four years, from 1847 to 1851.

† Extract from report of Commissioner of Crown Lands, 1861. I am indebted for this information to Mr. J. T. Judah, of Montreal, late Superintendent of Crown Domain and Jesuits' estate, Department of Crown Lands.

product, however, was chiefly used in the manufacture of car-wheels, and so the trade in stoves and hollow-ware gradually fell off.

The property is now owned by George McDougall, of Three Rivers, the furnace having been in blast till the summer of 1883, when, owing to the ore and fuel becoming exhausted, it was finally closed. When working, it was *the oldest active blast furnace on the American continent.*

This statement is made upon the authority of Mr. James M. Swank, late Secretary and now Vice-President and General Manager of the American Iron and Steel Association; a short account is given of the works in his "Statistics of the Iron and Steel Production of the United States," which he, as special agent, compiled in 1880, for the tenth census of the United States, and more recently in his *History of the Manufacture of Iron in all Ages*, published last year, wherein Mr. A. T. Freed, of Hamilton, Ont., and Dr. T. Sterry Hunt, of Montreal, are acknowledged as having contributed most of the information as respects these forges.

Through the kindness of Mr. F. C. Wurtele, Librarian of the Quebec Literary and Historical Society, and also of Mr. H. M. Price, of Quebec, I have been enabled to give fuller particulars than are furnished by Mr. Swank. In addition to those thus named, other authors and authorities have been carefully consulted in my endeavor to give a complete account of the Saint Maurice forges, from their rise to their close; for they are unique in the history of this country.

*Iron Works at Batiscan.*—About the year 1798, a blast-furnace and casting-house, two forges, a saw- and grist-mill, besides other workshops and dwelling-houses, were built on the east side of the Batiscan River, about six miles from its mouth. The works were situated in the seigneurie of Batiscan, County of Champlain, were in operation some little time, and were similar to those at St. Maurice; but the proprietor died, and the place was shut up. Both ore and wood are reported to have been more plentiful here than at St. Maurice.*

An interval of sixty years now occurs before we again hear of a new enterprise.

*The Radnor Forges.*—The Radnor forges at Fermont, in the seigneurie of Cap de la Madeleine, County of Champlain, are situated about ten miles from Three Rivers, on the Piles branch of the North Shore Railway, and were erected about 1860, by Messrs. Larue & Co.,† the firm consisting of Larue, Turcotte, and G. B. Hall & Co.

* Bouchette's *Lower Canada*, 1832.

† *Can. Geol. Survey*, 1863.

The establishment was extensive, consisting of a blast-furnace, forge, and large rolling-mill; a car-wheel foundry in Three Rivers, 40,000 acres of freehold land (timber and ore lands) also forming a part of the property. Sir William Logan, in his Geology of Canada, 1863, says: "The crude ore is brought to the furnace partly by the workmen of the company and partly by the farmers on whose land it is found. It is washed to free it from adhering earth, and then yields from forty to fifty per cent. of metal; about 2000 tons of cast-iron being now produced annually from between 4000 and 5000 tons of ore. The number of men employed at the Radnor forges varies from 200 to 400, a great many hands being required at certain seasons to dig up and bring in the ore, and to prepare and transport the charcoal.

"The chief manufacture of the company has, of late, been cast-iron wheels for railway-cars, for which the metal appears well adapted. A pair of car-wheels, which were said to have run 150,000 miles with an axle of this manufacture, were sent by Messrs. Larue & Co., the proprietors of the forges, to the International Exhibition of 1862. Wrought-iron is also made at this establishment, and a rolling-mill has recently been erected here, which furnishes iron for the manufacture of scythes and nail-rod iron."

The rolling-mill and forges, etc., have since been destroyed by fire, and at present the blast-furnace is in operation, turning out about four tons of iron per day. The ore is dredged up from the bottom of Lake Tortue, delivered on railway-cars, and carried direct to the furnace, whilst the iron is still used for car-wheels in the wheel-foundry at Three Rivers, now leased to Mr. George McDougall. Over a million dollars have been sunk in these works since their commencement, through bad management and disastrous fire.

*L'Islet Blast-Furnace.*—This furnace was built by the Messrs. McDougall, the proprietors of the St. Maurice forges, about four miles from those works,* but it has not been in operation for some years.

*Iron Works at Hull.*—In 1857 the Canada Iron Mining and Manufacturing Company of Montreal built a blast-furnace at Hull, near Ottawa, and, for a time, in that and the following year, produced a superior quality of pig-iron, but "the economic results not being satisfactory," the working was stopped, and the furnace, being much injured by a forest fire a few years afterwards, was abandoned.†

* *Geol. Survey*, 1873–74.

† *Geol. Survey*, 1866–9, 1873–4.

*Smelting in Yamaska.*—The St. Francis River Mining Company, in 1869 erected a blast-furnace in the County of Yamaska, near the Rivière aux Vaches, and kept it working until 1873, producing in that time 5520 tons of charcoal pig-iron. The property was purchased in that year by Messrs. John McDougall & Co., of Montreal,* and operated by them till 1880, when the bog-ores having been exhausted within a paying distance from the furnace, it was dismantled.

*Baie St. Paul Iron-Works.*—Two blast-furnaces, extensive buildings, and a railway from the works to the river, were completed in 1873 by the Canadian Titanic Iron Company, near Baie St. Paul, on the north shore of the St. Lawrence, about sixty miles below Quebec, for the purpose of smelting the titaniferous iron-ore of that region.† The furnaces were only in operation a short time, the cost of production being too great. The place was never worked again, and was dismantled in 1880.

*Grantham Iron-Works.*—Messrs. John McDougall & Co., of Montreal, in 1880 and 1881, built two blast-furnaces at Drummondville, on the River St. Francis, in the Township of Grantham, County of Drummond. They are still in active operation, and are known as the Grantham iron-works. The resident manager, Mr. Robert McDougall, has kindly furnished the following particulars: "The blast-furnaces are each thirty-four feet high, with boshes of eight and ten feet respectively. They are worked with hot and cold blast, and the air-pumps are driven by water-power from the River St. Francis. The fuel used is charcoal, and the bog-ore, which contains about 40 to 45 per cent. of iron, is obtained about three miles from the works. The annual capacity is 4000 tons, and the product charcoal pig-iron for car-wheel purposes."

A siding from the Southeastern Railway runs directly into the works, and the iron is made into car-wheels at the foundry in Montreal.

*Moisic Iron-Works.*—The Moisic Iron Company was originated in 1867 to work the iron-sands on the north shore of the Gulf of St. Lawrence.

Dr. Sterry Hunt, in his "Notes on Iron and Iron Ores," in the Geological Survey Report of 1866–69, says:

"The great deposits of black iron-sand on the beach near the mouth of the Moisic river having attracted attention, various attempts to reduce it were made. In January, 1867, Mr. W. M. Molson, of

* *Geol. Survey*, 1873–4.

† *Can. Geol. Survey*, 1873–4.

Montreal, had the ore successfully treated by the bloomary process, in northern New York, and the result proving satisfactory, several bloomary furnaces were, in 1867, erected by him at Moisic, and have since been in successful operation."

A forge and rolling-mill were subsequently erected in Montreal to work up the loops or blooms, which were made into forgings, etc., and also exported to the United States.

The proprietor having lost a large amount of money was obliged to close both the works at Moisic and those in Montreal, and they were dismantled and sold in 1876 or the following year. The action of Congress, no doubt, which prevented the export of the blooms to the United States by refusing to allow them to be classed as pig-iron, deprived him of the only market there was for that class of iron, and was the cause of the mercantile failure of the enterprise.

*Quebec Steel-Works.*—An attempt was made in Quebec to work these sands. Mr. B. J. Harrington, B.A., Ph.D., in his "Notes on the Iron Ores of Canada and their Development," in the Geological Survey Report of progress for the year 1873–4, thus describes it:

"In the month of June last, I had an opportunity of visiting the steel-works erected at Quebec for the purpose of manufacturing steel directly from the purified sands of the Gulf. Since the death of Mr. Labreche Viger, the works have passed into the hands of a new company, the president of which is Mr. Chinic, hardware merchant of Quebec. The enterprise, so far as I could learn, has not been successful, and at the time of my visit, nothing whatever was being done. The furnace is a well constructed Siemens regenerative furnace, with five gas-producers, and, except in the construction of the hearth, which is perfectly flat, and in one or two other minor details, resembles the one employed by Messrs. Cooper and Hewitt at Trenton, N. J., in the manufacture of steel according to the Siemens-Martin process.

"In making steel, the sand, which had been purified by Dr. LaRue's magnetic machine, was mixed with tar and charcoal-powder in a box containing revolving knives or beaters, and the mixture was then pressed into square blocks by means of a hydraulic press. The blocks were then piled upon the furnace-hearth and melted down to steel, which was finally tapped off into ingots containing about 200 pounds.

"The cause of failure I was not told, but difficulty was probably experienced in obtaining a regular and homogeneous product."

Mr. Chinic subsequently stated, "That further and rather more successful experiments have lately been made with the furnace, and ten or twelve tons of steel produced. A good deal of difficulty was experienced in pouring, and the ingots were frequently *honey-combed*, and after forging were liable to contain flaws. Not more than 500 pounds of steel were produced at a melting, which required six hours." Nothing more was done, and the works were abandoned.

*Haycock Iron-Works.*—In the winter of 1872–73, still quoting from Mr. Harrington, "The Haycock Iron Mine was opened, and about 5000 tons of ore raised." The mines are situated about eight miles northeast of the City of Ottawa, in the Province of Quebec, and the works consisted of a "steam saw-mill, bloomary forge, engines, pumps, steam-hammer, workmen's cottages, stables, etc. Some blooms were made and exported to England; the iron was of very fine quality, but the enterprise was not commercially successful and the place was closed, and has not for some years been used. The Ottawa Iron and Steel Manufacturing Company recently acquired the property.

*Experimental Works in Montreal.*—The Canadian Iron and Steel Company, of Montreal, were incorporated in 1881 to test an invention of Dr. George Duryee, of New York, for making wrought-iron direct from the ore. The process was patented, and was called the "blow-pipe process." Crude petroleum was the fuel used, it being dripped into a strong blast and vaporized. An experimental furnace had been built in Toledo, Ohio, and some iron is claimed to have been made there, with, however, very doubtful results; but the inventor, sanguine, after his kind, urged that by certain improvements in the furnace, eventual success could not be a matter of doubt.

A site was chosen in Hochelaga, a suburb of Montreal, and about a twelve-month was occupied in perfecting the machinery and getting everything ready. The furnace consisted of an iron cylinder lined with firebrick; the cylinder was inclined and made to revolve; it was 120 feet long and 5 feet in diameter for 100 feet, the remaining 20 feet being 10 feet in diameter. The iron-ore was ground fine and mixed with flux, and introduced into the elevated end of the cylinder and gradually worked down as the cylinder revolved. The heat from the combustion of the vaporized oil was intense; and when under its influence the particles of ore began to melt, they stuck together, and by the time they reached the "pud-

dling chamber" at the enlarged end, should have gathered into balls, which, when ready, were to be taken out and hammered into blooms.

The experiments were continued about twelve months, and iron-ore from Hull, Baie St. Paul, Moisic sand and bog-ores were tried with limestone, clay and quartz as flux, but although a small quantity of iron was produced, the experiments could not be called successful; and so after spending some $70,000 or $80,000 they were stopped.

*Montreal Iron-Works.*—In Montreal there are, at present, four rolling-mills which manufacture iron for their own use from wrought iron scrap and imported puddled bars. For tack-making the best quality of English sheet-iron is imported and Swedes charcoal tack-strips, the product being spikes, nails, horse-shoes, tack-brads, springs, bolts and nuts in the one case, and butt-welded iron pipe in the other. They may be enumerated as follows:

1. The Montreal Rolling Mills Company, which manufacture cut nails, pressed nails, horse-nails, tacks, brads, etc., and iron pipe butt welded. Both mills are worked by steam-power.

2. Pillow, Hersey & Co.'s works, which produce cut nails, railway and pressed spikes, horse-shoes, cut tacks, brad and shoe-nails, also carriage, tire and other bolts, coach-screws, hot-pressed and forged nuts, etc. The rolling-mill is run by steam, and the bolt-factory, etc., by water-power.

3. The works of Peck, Benny & Co., which produce nail-plate, cut nails, clinch and pressed nails, horse-shoes and horse-shoe nails, ship- and railway-spikes, and tacks of all sorts. These works are operated by water-power.*

4. The Metropolitan Rolling Mills, Abbott & Hodgson, proprietors, manufacture railway and ship-spikes, horse-shoes, clinch, pressed, cut, barrel, box and other nails. This mill is run by steam-power.

## II.

### Early Enterprises in Ontario.

The first attempt to manufacture iron in Ontario was made at Lyndhurst, then called Furnace Falls, on the Gananoque River, in the County of Leeds. This county was first settled in 1785, and its boundaries established by proclamation of the 16th July, 1792.

About the year 1800, a company composed of Ephraim Jones,

* Taken from Mr. W. J. Patterson's Board of Trade Report, 27th August, 1883.

Daniel Sherwood, Samuel Barlow and Wallace Sutherland erected a blast-furnace at the Falls, the water-power being no doubt utilized to drive the machinery and work the blast.

"The ore was of inferior quality and had to be drawn a considerable distance; consequently the enterprise was not a financial success, being abandoned after two years' trial. At one time, an attempt was made to cast hollow-ware for the use of settlers, including pots and kettles, but proved a complete failure." Such is the account given by Thad. W. H. Leavitt, in his history of the united counties of Leeds and Grenville.*

A forge for the manufacture of bar-iron was built about the same time for the same company, and was in operation until 1812, when, from want of capital, and on account of the derangement to business consequent upon the war of that year, the place was shut up and never opened again. The ruins are still visible.†

*Normandale Furnace.*—The next attempt made was in Western Ontario, at Normandale, then known as Potter's Creek, in the township of Charlotteville, in the County of Norfolk, in the then London district. The boundaries of the county were established by proclamation the 16th July, 1792, and the township contained 900 people and 132 inhabited houses in 1817.

In the year 1815, Mr. John Mason, an Englishman, undertook to manufacture iron, and in two years' time he had a blast-furnace in operation, which was "of a rude and primitive description, entirely the labor of his own hands, with the exception of the machinery for the blast. The bellows were formed out of two hollow whitewood trees. It is thus that the spirit of enterprise and necessity, which has so truly been called the mother of invention, enables an individual in this young country to overcome difficulties which in other situations would be considered insurmountable."‡

Mr. J. Harris, R. N., who furnishes the information, goes on to say in regard to the situation chosen for the furnace: "With respect to water they have a great advantage. Potter's Creek, though not large, is a never-failing stream. The works are situated at its entrance, immediately on the shores of Lake Erie, hence the great convenience of sending off their weighty manufactured articles, or of receiving any supplies which they may require, without the expense of land-carriage. Moulding-sand is abundant on the site of the

* Brockville, 1879, p. 62.

† I am indebted to Mr. S. McCameron, of Gananoque, and Mr. E. C. Slater, of Sweet's Corners, Ont., for these particulars.

‡ Lieut. Baddely's paper in Lit. and Hist. Soc., Quebec, 1830, vol ii., p. 420.

furnace, and timber for charcoal is easily obtained and in great variety; the hard maple is preferred."

In Robert Gourlay's *Statistical Account of Upper Canada*,* the following letter from Mr. Mason is to be found:

"POTTER'S CREEK, Dec. 4th, 1817.

"SIR,

"You desired me to give you every information in my power of the probability or certainty of making iron in this part of the province, so as to be beneficial to the manufacturer and the public. I will state to you what is for and what against. In favor of iron-works is the high price of iron and plenty of timber for coal; everything but these is against the first beginner. The bog-ore is scattered over the whole country, but I do not know of any one bed of ore that will exceed 120 tons. I spent three months in examining the country for ore, and I calculate that it will take all the ore I found within twenty miles of this place to supply a small furnace for seven years; but I believe considerable quantities within that space are not yet found. No rock ore has as yet been found in this part of the province, and if there is any, it must be at considerable depth from the surface of the ground and will be difficult to find, as the strata lie horizontal. Another thing against iron-works is that it will require many experiments before we can know the best method of working the ore, and there is not any stone in this part of the province that will stand the fire, and I believe it will be best if it comes from three different places in the United States. I want five or six pieces of iron, each 30 cwt., these will come to an enormous expense. I intended to ask the Government to give or lend me five or six disabled cannon for this. I asked the Government to pay the passage of five or six families from England to work in the furnace. This could not be granted, and therefore I would not ask for the cannon. Another thing against me is that there is not a man in the country that I know capable of working in the furnace. But the greatest difficulty I have to overcome is iron-men, as we call them, who are the very worst sort of men to manage, colliers not excepted. Not one of a hundred of them but will take every advantage of his master in his power. If I have just the number of hands for the work, every one of them will know that I cannot do without everyone of them, therefore everyone of them will be my master. Anxiety and trouble will be the consequence; and if I keep more hands than are necessary, so as to have it in my power to turn those away who will not do right, this will be expensive. But, after all, if the ore is as good as I expect, I hope to reduce the price of iron very considerably. The place where I am is a reserve lot. Governor Gore has promised encouragement to the works, when the Government is satisfied they will answer a good purpose. If Governor Gore does not return to this country, and what he promises should be refused me, iron-works will be at an end with me and at this place; but I shall not ask for the promise until the inhabitants of the country will be my bondsmen for the benefits arising from the iron-works. When I saw you I offered a considerable sum of money to take them off my hands; this I repeat, not but what I believe they will answer, but the trouble will be more than equal to any profit from them. Those who begin iron-works in this country after me will start many thousand dollars ahead of me, everything they want except stone will be had here, the best method of working the ore will be known, and men will be learned to work it.

"I am, sir,

"Your obedient servant,

"JOHN MASON."

* London, 1822.

Poor John Mason never reaped any benefit from his enterprise and perseverance. He had only made a few tons of iron when the inner wall of his furnace gave way and it became "bunged up," so that it was of no use. This discouraging event seemed to prey on his mind, and he sickened and died, leaving the property to his widow and son.

In 1820 the property was purchased by Mr. Joseph Van Norman, who is now in the 89th year of his age, and is living at Tilsonburg. The following particulars were obtained from him and kindly furnished by his son, Mr. G. R. Van Norman, Q. C., of Brantford.

In 1821 Mr. Van Norman formed a partnership with Mr. Hiram Capron, late of Paris, and Mr. George Tilson, late of Tilsonburg, and commenced building a blast-furnace, which was completed and put in blast in 1822, after an expenditure of $8000. The iron turned out was of excellent quality, and the ore fairly rich. It was bog-ore and was found in the swamps and marshes in the vicinity, being hauled in by wagon-teams, a distance varying from six to twelve miles. The average consumption per day was nine tons, producing about three tons of pig iron. The furnace would be in blast about eight or nine months out of the year, running night and day, and producing 700 to 800 tons of iron, with an annual consumption of fuel equal to 4000 cords of hard wood, made into charcoal in the usual way.

In 1830 the works were burnt down, but were immediately rebuilt on an extended scale.

In the early stage of the enterprise all the iron made was converted into various kinds of castings, there being no market for pig-iron; and as a consequence, the wants of the country at that time becoming overstocked, some was exported to Buffalo, and a vessel-load of stoves and castings sent to Chicago. The wares produced were disposed of along the shores of Lake Erie, from Fort Erie to Amherst Bay, and taken into the interior of the country by teams. Before the opening of the Welland Canal, stoves, kettles, and other iron-ware were sent very long distances by teams, particularly in winter, going as far as Chatham, Waterloo, and beyond St. Catherine's. After the opening of the Welland Canal (the first vessels passed through in the year 1829), places on the canal and Lake Ontario were accessible by water, and accordingly two vessels were employed by Mr. Van Norman, and kept busy during the summer. Hamilton, Toronto, Port Hope, Kingston, etc., were thus supplied, and from these centers the wares were distributed into the

back country. Some of the goods were sent as far as Montreal. The business seemed to be the right thing for the country, and started at the right time to be of use to the new settler, to furnish him his sugar-kettles and his kettles for boiling the ashes gathered from the burning of his log-heaps. At that time the potash made from these ashes was the only exportable article which could be shipped to foreign countries and for which money could be obtained.

There was in those days no money in the country, and business was carried on by barter or exchange of commodities. Anything the people had to sell was brought to the furnace and exchanged for the wares in payment, or due-bills were taken, payable in iron-ware. Due-bills were in this way used as a kind of circulating medium over a large section of what is now the Province of Ontario. At one time the books of the establishment showed outstanding over $30,000 of these demand due-bills for iron, and then for a time the practice was discontinued.

At the expiration of five or six years, Mr. Joseph Van Norman, who was the managing partner, and gave the name of Normandale to the locality, bought out his partners and took his brother Benjamin into the business; but he retired after a few years, and the concern was carried on in the name of J. Van Norman & Son till 1847. By this time both fuel and ore were well-nigh used up in the neighborhood of the furnace, and it was abandoned. The firm had also a forge in the vicinity of Port Dover, where for some years they carried on the manufacture of bar-iron for horse- and sleigh-shoes.

After the closing of the Normandale furnace, its owner paid a visit to the Marmora Iron-Works, which will now be described.

*Marmora Iron-Works.*—The Township of Marmora, in the County of Hastings, has long been noted for its iron-ores. "In 1821 the township was first advertised for sale, but from the rocky and swampy character of a large portion of the land it did not make much progress towards settlement, and, in 1850, only contained 593 inhabitants."*

The village of Marmora is situated on the Crow river, 41 miles from Peterboro, 32 miles N.N.W. of Belleville.

Iron-works were first commenced at Marmora about the year 1830 by a Mr. Hayes, who, after spending a large fortune and the fortune of his wife, had to give up the property to his creditors; the late Hon. Peter McGill, of Montreal, to whom over £40,000 was owing,

* Smith's *Canada*, 1851, p. 246.

in this way came into possession of the place, and the works were for a time carried on in his interest, under the management of a Mr. Manchan, who represented Kingston in the Upper Canada Parliament; but they resulted in a heavy financial loss.

In 1847 Mr. Van Norman visited the works and was tempted by the appearance of the great ore-beds in the immediate vicinity (the Blairton Big Bed) and the general appearance of the place, to continue to Montreal and see Mr. McGill; he did so, and bought the property for $21,000.

In the fall of the same year he moved to Marmora, and after expending a large sum in fitting up the furnace, putting in machinery, ovens, blowing-apparatus, erecting and repairing buildings, cutting cord-wood and making it into charcoal for fuel, everything was finally ready and the furnace was started the following summer. The result was a bitter disappointment, for after being used to an easily reducible bog-ore, Mr. Van Norman now had to treat a rock-ore, very rich in metallic iron. The amount of charcoal used per ton of iron was consequently very large, and nothing but loss attended every effort he made. After the iron was made it had to be carted thirty-two miles to Belleville, over rocks and "corduroy" roads so rugged that the wagons were constantly breaking down, and even the shoes of the horses were pulled off, roads existing merely in name. It was found absolutely necessary to get some new route, so a road was opened from the works to Healey's Falls, on the river Trent, a distance of nine miles, and the iron taken from there by steamboat to Rice Lake, and carted thence twelve miles to the dock at Cobourg.

Up to this time iron ranged in price from $30.00 to $35.00 per ton, and found a ready sale at these prices. In 1848, however, the St. Lawrence canals were completed, and England had adopted the principles of free trade, the consequence being that pig-iron was brought up and sold in Belleville and Cobourg at $16.00 per ton. This settled the question of making charcoal pig-iron for Mr. Van Norman, who quotes these prices. He had to stop the works and lose everything, not having even money enough left to get away from the place. Relief came, however, unexpectedly in the shape of a letter from Mr. McGill, expressing regret at his failure and inclosing a cheque for £100.

We shall again hear of Mr. Van Norman in iron-manufacturing enterprise, but must first complete the story of Marmora.

The next proprietor was a local concern from Belleville, called the

Marmora Foundry Company. A gentleman connected with the company furnished the following.*

"A company was formed in Belleville for the purpose of purchasing the property and making another attempt to work the mines. The Marmora Iron-Works, the property of the Marmora Foundry Company, are situated on lots Nos. 9 and 10, in the fourth concession of that township. The works, which are erected on the bank of the Crow River, a short distance from the foot of Crow Lake, are very extensive, and consist of two blast-furnaces of good size, one of which has been within a few months almost newly built and lined with Stourbridge brick, and is ready for use at any time when the operations of the company may be resumed. The blast (which is called the 'hot-blast') is furnished by a new and improved cylinder apparatus with air-heating ovens on the most approved principle, and is driven by a powerful and never-failing stream of water. This furnace has been in blast but for a short period, and that only for the purpose of testing the practicability of working the ore, so as to produce such a quantity of iron per diem, as would leave reasonable expectations of the manufacture proving profitable. The company therefore spared no expense in fitting up the furnace, which was done under the superintendence of an eminent iron-founder and practical assistants. The quantity of iron (pig) produced from this furnace was five tons per day of very superior quality, and it was found that the probable cost of manufacture in a blast of longer duration would not exceed three pounds, or three pounds five shillings per ton.

"Owing to some difficulty between the directors and a portion of the stockholders, who had refused payment of their stock, the works were stopped after this experiment, and will not probably be resumed for a year or two unless the company succeed in leasing the premises to some practical person, a course which they would prefer rather than carry them on in future on their own account.

"The premises of the company are very extensive, and comprise (in addition to the blast-furnaces and several large houses for storing charcoal) a large stone building with trip-hammer, for the manufacture of bar-iron, several stone buildings and houses, used for shops, boarding-houses, etc., and about twelve frame dwelling-houses occupied formerly by the work-people of the establishment, which are now rented out to various parties. There are also a flouring-

* Smith's *Canada*, 1851, p. 247.

mill, a saw-mill, and a building formerly a tannery, but now about to be converted into a clothing- and fulling-factory, all driven by the same stream (which is capable of propelling three or four times as much machinery from the same head) over which a very handsome and suitable bridge was built last year. A church (Roman Catholic), built of stone and of very neat construction, is situated nearly opposite the bridge, on the western bank of the stream. All of these buildings are on the property of the company, and form together a compact and flourishing village, in which is a post office. On the north side of the village, and also on the property of the company, a town-plot has been laid out, and a few lots sold, on which buildings are now being erected by the purchasers; but the whole of the grounds on which the buildings above described stand is intended by the company to be reserved for the purpose of leasing to tenants. On the south side of the village is a well-cultivated farm, with handsome dwelling-houses and suitable out-houses, gardens, etc., also the property of the company.

"The ore-bed (or rather the main ore-bed from which the furnace was supplied, for there are many valuable beds of magnetic iron-ore in the neighborhood and some of bog-ore) is situated on a high bank on the shore of Crow Lake; it is mined easily and loaded on board scows for transport to the works, from which the ore-bed is distant about three miles and a half. The ore is a magnetic oxide, very rich, three tons yielding two tons of iron. Excellent as is the cast-iron made from this ore, it is still more suitable for bar-iron, the toughness and ductility of that which has been made there giving it a preference to the best Swedish iron. Marble and lithographic stone are also on the property of the company; samples of the latter were sent to the great exhibition at London and received (as did also the iron and specimens of ore sent) favorable notices from the English press." From authentic accounts, this company sunk about £20,000 in their venture.

In 1856 an English company came to the fore. Mr. Wm. Hainsworth, now Superintendent of the Pittsburgh Steel Casting Company of Pittsburgh, Pa., one of the largest and most successful works of this sort in the United States, was sent out from England to Marmora, and Mr. Vernon Smith, who had just left the Woodstock Iron-Works of New Brunswick, took charge. He rebuilt the old furnace and afterwards built a new one cased with iron. The place seems to have been dismantled before he took charge; it was, however, again put into working order, but did not run long. Mr.

Smith says, "The iron was too rich for economical working in a blast-furnace, if flux was not very largely used; the iron being converted into wrought-iron and *burning*, not melting." By the time they stopped, Mr. Van Norman estimates they had lost not less than £70,000.

In 1866 one of the furnaces was put in blast by a Mr. Bentley, of Marmora, and remained working for forty days,* and in 1867 the property passed into the hands of an American company, which mined the ore and shipped it to Pittsburgh. In 1869 they amalgamated with the Cobourg and Peterboro' Railway Company, and have since been known as the Cobourg, Peterborough and Marmora Railway and Mining Company. They for some years shipped annually a large quantity of ore, a railway having been built on the same route Mr. Van Norman had opened to Cobourg.

In 1875 an attempt was made by Mr. W. H. Fraser, now of Ottawa, to smelt iron-ore with crude petroleum in one of the Marmora furnaces. In the proceedings of the Iron and Steel Institute of England, for that year, a short notice is given of it, but they "fear not much good will result." The experiments were not commercially successful.

*Madoc Blast-Furnace.*—In the year 1835 Mr. Uriah Seymour, of Wolcott, Wayne County, New York, took some iron-ore from Madoc, in the Township of Madoc, County of Hastings (not very far from Marmora), and tried it in his furnace at Wolcott, and two years afterwards built a blast-furnace at Madoc. He was never able to produce much iron, but succeeded in losing all his means, and his partner having been killed in the mine, Mr. Seymour closed up, and the place has never since revived.†

*Houghton Iron-Works.*—We now hear again of Mr. Van Norman, and with him of the last smelting-enterprise in the Province. After his failure at Marmora, he returned to his old home at Normandale. About this time the Great Western Railway (now G. W. Div. G. T. R'y) was under construction. Messrs. Fisher and McQueston, of Hamilton, Ont., were furnishing car-wheels to the Company and had a great deal of trouble to get charcoal iron suitable for making car-wheels. The iron formerly made at Normandale was just the kind which was wanted, and an offer was made by them to Mr. Van Norman, to take all the iron he could make, at a price which promised to pay well, viz., $45.00 per ton. A contract

* *Can. Geol. Survey*, 1863, p. 676, and 1866, p. 108.

† *Can. Geol. Survey*, 1863, p. 675, and 1866, p. 109.

was entered into, a clause being therein inserted, providing that the iron should be suitable for the manufacture of car-wheels. A person was at once sent into the Township of Houghton, in the County of Norfolk, to prospect for bog iron ore, and on his having reported that it could be found in sufficient quantities, a blast-furnace was at once built and placed in operation in the fall of 1854. In the following spring, 400 tons of iron were shipped, but upon being tested this iron was rejected, as it would not chill. It had to be sold and only brought $22.00, which was below the cost of production; so the works, which had cost about $30,000, were abandoned, and Mr. Van Norman's career of over thirty-four years in the blast-furnace business ended, he having unfortunately lost at Marmora and Houghton all that had been made at Normandale.

*Furnace Falls Iron Company.*—After an interval of eighteen years, during which time a number of projects had been talked of, a blast-furnace was commenced in 1882 by Messrs. Parry and Mills, of Chicago, at a place they named Furnace Falls, on the Burnt River, in the County of Haliburton; but, after an expenditure of about $35,000, the works were stopped for want of capital to complete them, and they still remain in this unfinished condition.

Apart from blast-furnaces, a number of other iron industries have, at various times been, and some are still, in operation. They may be enumerated as follows:

*Toronto Rolling-Mills and Iron-Works.* — About 1860 Messrs. Gzowski and Macpherson, of Toronto, started a large rolling-mill in that city for the special purpose of re-rolling iron rails; some bar-iron was also made out of scrap. The works were situated in the east end of the city, on the south side of South Front street. About 1873 the place was closed and dismantled, and the land is now owned by the Grand Trunk Railway Company, it being at present the site of their car repair-shops. The cause of the mill being closed was the substitution of steel for iron rails.

In 1866 the Steel, Iron, and Railway Works Company was organized in Toronto and a charter granted by the Ontario Legislature.* The authorized capital stock was $115,000, and the special object of the company was to operate a patent granted to a Mr. Hugh Baines, and dated 27th July, 1865, "for making railroad crossing points, and for putting steel ends or sections on railroad

* Cap. 110, 26-30 Vic.

rails." The works were situated in the west end of Toronto, on the west side of Strachan Avenue, alongside the Great Western (now G. W. Div. G. T.) Railway, and their operations were confined to patching iron rails and making some forgings. The adoption of steel rails closed the works, but they were resuscitated in 1872 by being merged into the Canada Car and Manufacturing Company, a concern chartered by the Provincial legislature,* with an authorized capital of two million dollars, for the manufacture and leasing of railway cars.

"On the 9th of August, 1872, a contract was entered into by the Government of Ontario and the Canada Car Company of Toronto, under which the Government leased to the said company for a term of seven years and a half from 1st January, 1874, the labor of all the prisoners sentenced to the Central Prison, except such as was required to carry on the domestic work of the prison.

"This contract provides that prisoners shall not be sentenced to the prison for a shorter period than three months, and that they shall not, through physical or mental defects, be unfit to perform an ordinary day's labor, consisting of ten hours per day, less two hours every week. The Government is to furnish sufficient workshop space (with foundations for machinery and other permanent fixtures) properly heated and lighted, to enable the industry to be carried on, and the boilers, engines and shafting required for motive purposes, not exceeding one hundred horse power,—the engineers and firemen to be provided by the Company as well as the fuel for the furnaces.

"The Company is to employ the prison-labor thus leased, in the manufacture of railway-cars, in all its various branches and requirements, as well as in the maufacture of nails, bolts and spikes of every description, etc.

"For the prison-labor thus leased the Government is to receive from the Company the sum of fifty cents per day for each and every prisoner during the first two and a half years' existence of the contract, for the second two and a half years fifty-five cents, and for the third and last two and a half years the sum of sixty cents per day."†

The Company's premises adjoined those of the central prison, which was in course of construction. The prison buildings were

* Cap. 114, 36 Vic.

† Extracts from Report of Inspector of Prisons, etc., for 1871-2-3. Sess. Papers, Ont., No. 27, 1874.

not designed for this class of manufacture, but were altered and made to answer, several railway-sidings were laid and the appliances put in were of the latest description. There were also introduced a forge with four large beam-hammers, and the necessary furnaces and plant for the manufacture of locomotive and car-axles, and large forgings out of scrap-iron; several small hammers, a wheel foundry equipped to turn out 120 car-wheels per day, a large foundry for soft castings, and shops and machinery for making bolts, nuts, washers, together with a variety of iron- and wood-working tools. Large stocks of wood, iron, coal, etc., were laid in for an extensive business.

From 200 to 350 prisoners were now ready, and their wages of fifty cents per day had to be paid. About this time a period of very severe depression set in, and orders for cars were not to be had at any price, and after building about 100 or 200 cars, and altering some trucks for the Intercolonial Railway, the Company collapsed, and the place was subsequently dismantled and sold.

*Hamilton Rolling-Mill.*—About 1864, the Great Western Railway Company erected a rolling-mill at Hamilton (which cost about $107,000, and had a capacity of about 7000 tons per annum*), to patch and re-roll iron rails; it continued in operation till the 8th March, 1872,† when it was closed. In 1879 it was leased to the Ontario Rolling Mill Company, which is still in operation, and is manufacturing bar-iron, nail-plate, and fish-plates, out of wrought scrap. The mill has now a capacity of about 12,000 tons per annum. A nail-factory is run in connection with it.

*Steel Works at Niagara.*—A venture in the way of steel-making was tried in 1873, when Date's Patent Steel Company was formed in Toronto, with a capital of $50,000, to manufacture steel under a patent granted the 23d December, 1872, to H. H. Date and F. H. Date, for a new process of converting iron into steel, and known as "Date's steel-converting process." A charter‡ was obtained, and complete works for the manufacture of edge-tools, etc., were erected at Niagara. The product of the factory proved uncertain. Some of the tools, such as axes and hammers, would stand the most severe treatment, whilst others would not, and thus the goods were so unreliable as to be unsalable, and the place had to be closed. Last year some experiments were made there by Mr. A. G. Wright, of Toronto, in the same direction, but with similar result.

* The Railways of Canada. Trout, 1870–71, p. 93.

† G. W. R. Report.

‡ Chap. 123, 36 Vic.

*London Steel-Works.*—The London Steel Works Company, of London, Ont., started in 1883, and built works containing one 30-pot Siemens melting-furnace, and a rolling-mill, driven by steam, with a ten-inch train of rolls, the annual capacity being 3000 tons of cast-steel. The works were put up specially to make steel castings and the Washburn patent car-wheel, which has a cast-iron center, and homogeneous cast-steel tire. The Company proposed also to make bar-steel flats and rounds, coil-springs and the best qualities of bar-iron. In 1884 a new puddling furnace was built and steam-hammers put in, to make steel and semi-steel by a new process, but, these following in the wake of their predecessors, the concern failed and the place was closed.

*Forge at Hamilton.*—The Hamilton Iron Forging Company, of Hamilton, Ont., make car-axles and forgings out of wrought scrap and have a complete forge. They commenced about 1878 and are still running.

## III.

### The Manufacture of Iron in New Brunswick.

This Province has not witnessed many attempts to manufacture iron, only one smelting-works having been built. In 1836 iron-ore beds were discovered at Woodstock, in the County of Carleton, by Dr. T. C. Jackson, of Boston, Mass., during a geological survey conducted under his guidance, by the authority of the State of Maine.*

About 1848 The York and Carleton Mining Company obtained a subsidy from the Provincial Government of 10,000 acres of picked land, and expended altogether about $30,000 in erecting a blast-furnace, two blowing-engines, a helve-hammer, operated by a separate small engine, boilers, buildings, etc. Within a year or two, the works and the furnace were injured by a fire. Repairs were made, and the works again put in operation. Another misfortune overtook them. Charcoal was used as fuel, and it one day happened that some small repair necessitated the stoppage of the blowing-engines for a few hours. With the object of saving the charcoal, the furnace was "banked" by piling sods on the top of it; there was a large "receiver" between the two blowing-engines, and by some mistake, the air-valves were left open, gas generated in the furnace, which being "banked" prevented its egress to the outside, and caused it to "back up" through the open valves into the

* *Mines and Minerals of New Brunswick*, by Prof. L. W. Bailey, 1864, p. 55.

air-pipes and receiver. After a stoppage of about four hours, the engines were started again, and on the second revolution an explosion took place, which wrecked the furnace and buildings, and ruined the Company. Mr. Vernon Smith, C. E., who kindly furnished most of the foregoing particulars, came out from England about 1854, as the agent of Mr. Charles Sanderson, of Messrs. Sanderson Bros., of Sheffield, for the purpose of making iron to be used in the manufacture of steel, as, owing to the war with Russia, the supply of iron from that country was stopped.

The works were now rebuilt, and remained in operation for about eighteen months, during which time about 1,000 tons of iron were made. They were then closed and remained idle for some years.

In 1862 the property passed into the hands of Messrs. Morris Best and Ellis Smith, who worked it as "The Woodstock Charcoal Iron Company." White pig-iron was made and exported to England, and was used by Messrs. John Brown and Co., of Sheffield, in the manufacture of armor-plates. Although the iron made is said to have been of superior quality, the cost of the production was too great, and as a consequence the place was closed and has not been operated since. The Woodstock ores are very lean and contain a large proportion of phosphoric acid, besides being very difficult to concentrate. The furnace was situated in the village, about three miles from the ore-deposits.

*Works for the Manufacture of Wrought-Iron, etc.*—The most important of these was incorporated in 1873, as the Coldbrook Rolling-Mill Company,* with a capital stock of $1,000,000, for the manufacture of bolts, screws, axes, rails and railway-iron, boiler-plate, rivets, tools, implements, machinery, etc. A rolling-mill was built at Coldbrook, three miles from St. Johns, N. B., on the Intercolonial Railway, and a nail-factory in connection with the mill was situated a mile or two away on the hill-side, and driven by water-power. Old iron rails and scrap-iron were the raw materials used and were converted into nails, spikes, bar-iron and ship-knees.

The works were in full blast for some years, when the Company failed, and the place lay unused and idle till last year, when the property was purchased by Messrs. I. and E. R. Burpee, of St. John, who are now working it. They advertise that they are now prepared to supply common, refined and horse-shoe bar-iron, nail-plates, mine

* Cap. 121, 36 Vic.

rails weighing eighteen pounds per yard, angle-iron, fish-plates, and ship-knees and straps.

*Iron-Works in St. John.*—The Portland Rolling-Mill makes nail-plate, forgings, car-axles and ship-knees, etc., out of wrought scrap. The mill is in Portland, a suburb of St. John, and is owned by Messrs. James Harris and Co., the car-builders who manufacture, amongst a variety of other things, the Washburn patent car-wheel, which has a steel tire, cast homogeneously on a cast-iron center.

Messrs. J. A. and W. A. Chesley make forgings, ship-knees, etc., at their rolling-mill in Portland, St. John.

## IV.

### The Manufacture of Iron in Nova Scotia.

A discovery of iron-ore was made in the year 1604, by the Sieur de Monts, who had been appointed the previous year Lieutenant-General of Acadia, by Henry IV. of France. He sailed from Havre de Grace the 7th April, and arrived at a harbor on the southeastern side of Acadia. After some explorations around the coast, he doubled Cape Sable, and anchored in St. Mary's Bay. Here they remained several days, and, while surveying the coast, discovered a vein of iron-ore.* At St. Mary's Bay, west of Digby, titaniferous iron-ore is found as sand, forming bands of irregular extent in the beach, the indications being extensive.†

"The first attempt to manufacture iron was made in the first decade of the present century, when a small quantity of bar-iron was made in a Catalan forge from the ores at Nictaux." ‡

*Moose River Iron-Works.*—The next enterprise is thus described, by Haliburton in his History of Nova Scotia: § "In the year 1825 an association was formed for the manufacture of iron, called the Annapolis Mining Company, with a capital of £10,000, divided into one hundred shares of £100 each. An Act of Incorporation was passed by the Legislature, and the Governor was authorized to grant to the Company a charter under the Great Seal of the Province. It was also protected by a clause of the Act, which provided that no stockholder should be liable for any debts contracted

---

* *The Pioneers of France in the New World*, Parkman, p. 220. Also compare *History of Nova Scotia*, Haliburton, 1829, p. 12.

† *Mines of Nova Scotia*, Gilpin, 1880.

‡ Nova Scotia *Mines Report*, 1877, p. 43.

§ 1829, p. 162.

by the Company, beyond the amount of his shares. As a further encouragement, two bounties of £600 each were offered for the manufacture of a certain quantity of hollow-ware and bar-iron. The associates immediately purchased an extensive and valuable vein of ore, situated about three and a half miles from the mouth of the Moose River, and another of equal importance at Nictaux, in the upper part of Annapolis Township, with one or two of smaller extent in other places. The local superiority of the former place gave it a decided superiority over any other part of the country, being distant only eight miles from Annapolis, twelve from Digby, and fifty from St. John, N. B., accessible by water, and affording a good anchorage. They therefore selected the eastern bank of the Moose river as the site of their buildings, and erected a large smelting-furnace, coal-houses, stores, etc. (Mr. Cyrus Alger was the superintendent.*) The extensive forest at the head of the river supplied them with an abundance of charcoal.

"They have already (1828) manufactured a quantity of hollow ware, and are now engaged in laying the foundations of forges, for making bar-iron. To carry these objects into effect, they have increased their capital to more than twice its original amount. The quality of the ore has now been ascertained, and the only part of the experiment yet to be decided is, whether they can compete with the English ware, or whether the cost of production will not exceed the value of the article when manufactured, a result which must depend very much upon the economy and skill with which the establishment is managed."

The works were only in operation a short time when "they were suddenly suspended, owing to political causes, but not before excellent iron had been produced, both pig-iron for foundry purposes and refined bar-iron."† For thirty-three years the works were closed, and when operations were resumed, it was for a short time only, to be again neglected for ten years more. In 1872 one hundred and sixty tons of pig iron were made and shipped to Boston, but since that time nothing has been done.

*Experiments in Pictou County.*—In 1828 an attempt was made by the General Mining Association to smelt some clay-iron-stone and East river ore, in a foundry-cupola, at the Albion Mines, Stellarton, and, as might have been expected, the experiments were not a success.

---

* Mines Report, 1877, p. 43.

† Mines Report, 1877, p. 43.

*Nictaux Furnaces.*—Two blast-furnaces were built at Nictaux (one in 1856), but they did not remain long in blast, and the iron produced is said to have been of poor quality, on account of "the phosphorus in the ores." In 1874 the furnaces were "in ruins, having been partly torn down by the people in the neighborhood to obtain the bricks."*

*Bloomfield Furnace.*—About 1860 a blast-furnace was put in operation at Bloomfield, to smelt the bog-ores of that district, and it has been in blast several times since then.†

*Acadia Iron-Works.*—We now come to the most important iron works of the Dominion, viz., those at Londonderry. The great vein of the Acadia mines was discovered by the late Mr. G. Duncan,‡ of Truro. In 1845, Dr. Gesner, and in 1846, Mr., now Sir William Dawson, visited and reported on the iron-deposits in the Cobequid Hills; and again, in 1849, Sir William Dawson, this time in conjunction with Mr. J. L. Hayes, of Portsmouth, N. H., went over the ground; and their report made to Mr. Charles D. Archibald, of London, resulted in the property being developed,§ and a charcoal blast-furnace, with the necessary buildings, being built in 1853 by the Acadia Mining Company. In 1850 a Catalan forge was put up, and a small quantity of bar-iron made, but this was discontinued, when the furnace was put in blast. The charcoal blast-furnace, which was built in 1853, continued in blast till 1874, and it is estimated produced about forty-five thousand tons of pig-iron. Sir William Fairbairn speaks of the Londonderry iron as follows:‖

"The specular ore of the Acadian Mines, Nova Scotia, is said by Dr. Ure, to be a nearly pure peroxide of iron. . . . . The Acadian ores are situated in the neighborhood of large tracts of forests capable of supplying almost any quantity of charcoal for the manufacture of the superior qualities of iron and steel. Several specimens of iron from these mines have been submitted to direct experiment, and the results prove its high powers of resistance to strain, its ductility, and adaptation to all those processes by which the finest descriptions of iron and steel are manufactured.

"The difficulties which the Government have had to encounter

---

* *Can. Geol. Survey Report*, 1874. Harrington, "Iron Ores."

† *Mines of Nova Scotia*, Gilpin, 1880.

‡ *Natural History Society*, Montreal, vol. vii., p. 134.

§ *Acadian Geology*, Dawson, p. 582.

‖ *Iron, its History, Properties, and Processes of Manufacture*, by William Fairbairn, F.R.S., F.G.S., p. 34.

during the last two years, in obtaining a sufficiently strong metal for artillery, are likely to be removed by the use of Acadian pig-iron. Large quantities have been purchased by the War Office, and experiments are now in process under the direction of Lieutenant-Colonel Wilmot, Inspector of Artillery, and the writer, which seem calculated to establish the superiority of this metal for casting every description of heavy ordnance."

The site chosen by Mr. Archibald for the furnace and buildings was on the west branch of the Great Village River, immediately on the ore-deposits of that place. The nearest shipping point by water was at Great Village, some six miles away, and there were no means of communication except by teams. The importance of obtaining railway-communication was very great; so, when the Intercolonial Railway surveys were being made in 1864, Mr. John Livesey, who at that time represented the iron-works, exerted himself to get the railway as close as possible to the works.

Mr. Sandford Fleming, in his *History of the Intercolonial Railway*, says: "Mr. Livesey continually urged, both privately and officially, the importance of locating the railway on a route passing close to the iron-mines in which he was interested. . . . . The working season of 1865 was occupied in surveys. Every pass across the Cobequid Mountains, within the limit of the iron-district, was examined, and every effort made to secure a practical line near the iron works."

The Chief Engineer, Mr. Fleming, favored a line which did not run close to the works, and a discussion was carried on very warmly in Nova Scotia. The matter had finally to be referred to Ottawa, as in 1867 the provinces were confederated, and the Dominion came into existence.

Six different routes had been surveyed; and one of them, a sort of compromise, was finally adopted by the Dominion Government, and by a letter of the 6th November, 1868, the Chief Engineer was instructed to carry it out. Mr. Fleming goes on to say: "Thus the controversy was ended; and hence arose that gigantic and conspicuous sweep, which the railway-traveller will observe on the southern flank of the Cobequid Mountains, where the line describes nearly half a complete circle. So marked is this feature in the location, that the popular voice has applied to it the term, 'The Grecian Bend,' which possibly may be retained so long as the railway endures."

In October, 1873, the Acadia iron-mines were purchased by the Steel Company of Canada (Limited). In the previous year, Dr. A.

R. C. Selwyn, F. G. S., Director of the Geological Survey of Canada,* made a report on the Acadia iron-ore deposits.

The property consisted of 55 square miles of freehold-land, with all the mines and minerals. Dr. Siemens was the chairman of the company, and they proposed to work the main bulk of the ore by Siemens' direct process for the production of iron and steel. Two of the furnaces were rotators, specially designed for the work, 9 feet in diameter and 8 feet long, and were revolved by machinery, others were afterwards built 7 feet in diameter by 10 feet long.

About two and a half million dollars were spent in opening the mines, building tramways, furnaces, a rolling-mill, coke-ovens, etc., and in 1877 over 10,000 tons of pig-iron were produced, and the amount has been increased every year since.

Although the works were built with a view to the manufacture of both cast and spring-steel of the very finest description, this was not carried on for any length of time, and a large portion of the plant has since been discarded. Probably the sudden stoppage of the proposed construction of the Canadian Pacific Railway by Sir Hugh Allan, made a change in the product necessary, and the company never made any steel rails, but turned its attention to bar-iron, nail-plate, car-axles, car-wheels, castings and pig-iron. The brand is "Siemens," and the quality of their products is the very best.

Like all pioneer enterprises, they have had a great many difficulties to contend against, and it is much to be regretted that the company is now in liquidation, and its property is for sale. They advertise that their works consist of "two modern blast-furnaces, 19 feet bosh, 65 feet high, with Siemens, Cowper & Ford's patent hot-blast stoves,† spacious stock-houses, and all necessary tracks and rolling stock, 67 bee-hive coke ovens, puddling forge and rolling mill, including car-axle plant, capable of manufacturing 10,000 tons of iron per annum, a car-wheel foundry of a capacity of 100 wheels per day, machine, pattern and carpenters' shops, dwellings, etc. Also the Chignecto and St. George Coal Mines, situated near Maccan, Cumberland County, N. S., together with 1500 acres of land well timbered. The Chignecto Mine is fully developed, and thoroughly equipped for raising and delivering 400 tons of coal per day."

*Halifax Iron-Works.*—In addition to the iron-works already men-

* Report of Progress, 1872-3.

† These stoves were the first set of firebrick stoves erected on the continent of North America. Swank, p. 327.

tioned, there is a rolling-mill at Halifax, where scrap-iron is worked up into nail-plate, ships' knees, etc., by the Halifax Rolling-Mill Company.

*Forge and Steel-Works in Pictou County.*—The Nova Scotia Forge Company, at Trenton, near Glasgow, in the County of Pictou, are situated on the East river bank; they have very complete appliances for forging all classes of work out of scrap-iron; they make ships' knees, steamship and mill-shafts, and specially car-axles. Probably more work is turned out from this shop than from any other forge in Canada.

The Nova Scotia Steel Company's Works adjoin the forge. These steel-works are the only ones in the Dominion; they were completed in 1883, their first cast being made on the 25th July of that year. One 15-ton open-hearth Siemens' furnace, gas-producers, a reheating-furnace, with two trains of rolls, one 16 and the other 28-inch, complete the steel-making plant. The mill is driven by a reversible steam-engine of the latest type, and steam is furnished by seven multitubular boilers.

The works have an annual capacity of 9000 tons, and produce plates, bar, spring and machinery steel, from hematite pig and steel scrap. Everything is very compact and complete about the works, which are well situated on the banks of the East river, a short distance below Smelt brook, between the river and the line of the Intercolonial (Pictou and Truro Branch) Railway. Vessels can unload direct into the company's premises, and the railway has a siding into the works, so that shipping facilities by rail or water are equally good. The Pictou Coal Field being only a mile or two distant, fuel is very cheap. A nail-factory for cutting steel nails has recently been established in connection with the works.

---

## *THE SYDNEY COAL-FIELD, CAPE BRETON, N. S.*

BY W. ROUTLEDGE, M.E., MANAGER OF THE RESERVE COLLIERY, CAPE BRETON.

(A Communication to the Secretary.)

As is well known, the Sydney coal-field comprises an area of about 200 square miles, being about 32 miles from the mouth of Big Bras d'Or, on the northwest, to Mira Bay on the southeast, by about 6 miles in width. The whole of this area is underlain by

valuable seams of bituminous coal, ranging from 2 feet up to 9 feet in thickness and lying at angles varying from 3° up to 40°, the dip of the greater portion being from 5° to 12°, and only in one place, at Victoria mines, amounting to 40°, as the result, no doubt, of some extraordinary upheaval.

The seams of coal in this coal-field are of the bituminous or soft variety, and all yield a coal well adapted for general purposes, while the product of some of them is specially applicable to the manufacture of gas. Much of it will compare very favorably with the best English coals. The aggregate thickness of coal in workable seams in the several basins (hereafter named) in the Sydney coal-field is from 25 to 60 feet; and as a rule the seams dip at a low angle and, so far as is known, are not affected by faults or dikes. As all the strata dip seaward, much of the coal will be available in the submarine as well as in the land-areas.

Although the Island of Cape Breton possesses so large an area of coal-bearing strata, very little has been done beyond explorations, except in the eastern or Sydney coal-field, where a number of first-class collieries have been opened, fully proving the extent of the field and also the approximate depth of the coal-measure.

Although geological surveyors and explorers generally make an attempt to connect continuously the several seams in the Sydney coal-field from one end to the other, it seems on a careful study of outcrops and sections that this field is practically composed of four separate basins, viz.: the Sydney mines, Lingan, Glace Bay, and Cow Bay basins. The great difference in the depth of seams in the several basins, and, moreover, the opposite curvature of the lines of strike of seams in the Sydney coal-field, and the fact that the dips on the north and south sides of Sydney River, and also Lingan Bay, are at right angles to each other, give strong presumption of the existence of these four separate basins in the field. The delineation of well-known lines of outcrop tends to show that what is here called the Glace Bay basin is elliptical in form, as the Cow Bay basin undoubtedly is, from proof in the workings of the Block House mines at Cow Bay.

The four basins may be described as follows:

No. 1, extending from the mouth of Big Bras d'Or River eight miles southward to Sydney River, and comprising what is generally known as the Sydney Mine Section.

No. 2, extending from Sydney River south about five miles to the shore of Lingan Bay, and usually termed the Lingan Tract.

No. 3, extending from the southern shore of Lingan Bay about eleven miles southward to the northern head of Cow Bay, and generally known as the Glace Bay Section.

No. 4, extending about four miles westwardly inland from the shore of Cow Bay and southwardly under the waters of Cow Bay, called the Block House Section.

No. 1. *The Sydney Mine Section.*—This basin contains four valuable seams of coal, besides a number of smaller ones, all lying at an easy angle of about 7°. The coal-seams in this basin are much thicker southward on Sydney River than to the north on Bras d'Or; but openings that have been made show that the quality of the coal remains uniformly the same. The southern termination of this basin may be supposed to be about at the middle of Sydney River, the seams of coal being broken off by what may be termed a submarine anticlinal, known as Petrie's Ledges, a dangerous reef of rocks running nearly the same course as the river.

A section of this basin shows the following important seams in descending order.

| | | | | Thickness. Feet. | In. |
|---|---|---|---|---|---|
| No. 1. Cranberry Head seam | 21 | feet down, | . . . . | 4 | 0 |
| No. 2. Lloyd's Cove " | 302 | " | . . . . | 6 | 0 |
| No. 3. Chapel Point " | 665 | " | . . . . | 2 | 0 |
| No. 4. Sydney Main " | 1030 | " | . . . . | 6 | 0 |
| No. 5. Indian Cove " | 1500 | " | . . . . | 4 | 8 |
| No. 6. Shaley " | 1690 | " | . . . . | 3 | 0 |
| Total thickness of workable seams, | | | . . . | 25 | 8 |

With the exception of Chapel Point seam and Shaley seam, all the seams in this section have been worked to some extent. The Main seam at the Sydney mines has been worked for more than forty years, and produces a first-class domestic coal. Lloyd's Cove seam has been partially worked by the owners of Sydney mines, but operations ceased in this seam about twenty years ago, owing to the ability of the company to supply all the demand from one pit. This seam has a stone band about two feet from the top, which does not seriously damage the character of the coal. The Indian Cove seam has also been worked in this district by the General Mining Association of London, at their No. 3 Pit at Sydney mines, on Ingraham's coal area on the Bras d'Or road, and by parties owning mining areas on Little Bras d'Or River; but the character of the coal was not such as to bring a paying price in the various home

and foreign markets, and all workings on this seam have been abandoned except by the farmers, who mine for home-consumption. The only colliery at present working on this basin is the pioneer colliery of Cape Breton, the Sydney mine.

No. 2. *The Lingan Tract.*—By crossing Sydney River to the south, Basin No. 2, or the Lingan tract, is reached. It extends five miles southwards from the southern shore of Sydney River to the northern head of Lingan Bay, and is underlain by valuable seams of coal, only one of which is less than three feet thick. The angle of dip in this basin is peculiar. At the Lingan or southern end the seams lie at an angle of 12°, whereas at the northern end, on Sydney River, the angle increases to 40°.

The following seams, in descending order, are found in this basin.

| | | Thickness. Feet. | In. |
|---|---|---|---|
| No. 1. Carr's | seam, 30 feet down, | 4 | 0 |
| No. 2. Barrasois | " 260 " | 8 | 0 |
| No. 3. Dunphy's | " 300 " | 4 | 0 |
| No. 4. Davy's Head | " 360 " | 7 | 0 |
| No. 5. Northern Head | " 650 " | 3 | 0 |
| No. 6. Lingan Main | " 700 " | 8 | 6 |
| No. 7. Laffin's | " 750 " | 2 | 8 |
| No. 8. Small | " 860 " | 2 | 3 |
| Total thickness of coal, | | 39 | 5 |

All the above seams have been proved to some extent by the farmers and fishermen on the shores of Sydney River and Lingan Bay. The Lingan Main seam has been extensively worked by the General Mining Association of London, at their Lingan mines, and is found to yield an excellent gas-coal. In this seam, workings are extended for some distance under the sea, where the coal retains its usual good character. Three feet from the top of the Lingan Main seam, where it is exposed in the cliff on the northern side of Lingan Bay, there is a stone band one inch in thickness. This band continues to increase in thickness until, about 1000 yards northwest from the shore (low water level line), the seam is divided by a band 14 feet thick. From this point the band gradually decreases till the seam nearly becomes united again.

The Ross or Davy's Head seam has been extensively worked by the Victoria Coal Company at the Victoria mines on the southern bank of Sydney River. The coal from this seam was largely used for domestic purposes, and is much appreciated in the various markets.

The Barrasois seam, cropping out at the surface about half-way between Lingan and Victoria mines, has been proved with a slope by the General Mining Association. As no sales of any moment have been made from this seam, the character of the coal is not known; but from appearances it will probably prove a good domestic coal. So far as the slope has gone down, the dip is very slight and does not approach in amount the dip at the Lingan or Victoria mines.

At the southern or Lingan end of this basin is the anticlinal which without doubt terminates this basin. The thickness of coal-measures proved is about 1000 feet.

No. 3. *The Glace Bay Section.*—On the other side of the Lingan basin, to the south, is basin No. 3, in which there are not less than fourteen seams, eight of which are over three feet in thickness. The depth of the coal formation is already proved to 3000 feet. In extent of area, number of seams, and quantity of coal, this is the most valuable of the several basins composing the Sydney coal-field. It yields coal of the best kind for the manufacture of gas and for domestic and steam purposes; and it possesses the largest number of collieries in actual operation, and the best railway facilities, giving access to the famous harbors of Sydney and Louisburg. Two important railways intersect it, both running within easy distance of the several coal-areas now worked, as well as of areas owned by speculators with license to work in the future. The seams already proved are, in descending order, as follows:

| | | Thickness. Feet. | In. |
|---|---|---|---|
| No. 1. Hub | seam, 240 feet down, . . . . | 9 | 6 |
| No. 2. Harbor | " 770 " . . . . | 5 | 6 |
| No. 3. Boutelier | " 1030 " . . . . | 3 | 0 |
| No. 4. Back Pit | " 1080 " . . . . | 4 | 6 |
| No. 5. Phelan | " 1190 " . . . . | 8 | 0 |
| No. 6. Ross or Emery | " 1330 " . . . . | 4 | 6 |
| No. 7. Small | " 1420 " . . . . | 2 | 6 |
| No. 8. Lorway | " 1830 " . . . . | 4 | 0 |
| No. 9. Gardiner | " 2290 " . . . . | 4 | 9 |
| No. 10. Gardiner (New) | " 2400 " . . . . | 5 | 6 |
| No. 11. Clarke's | " 2850 " . . . . | 2 | 0 |
| No. 12. Martin's | " 3100 " . . . . | 2 | 0 |
| Total thickness of coal, | . . . . | 55 | 9 |

All the above seams down to No. 6 have been proved to some extent by small workings in the cliffs, from Glace Bay Head round to Lingan Sand Bar, which clearly show their thickness and angle

of dip. Below No. 6, the several seams have been fully proved by pits, borings, and working slopes.

The upper or Hub seam has been extensively worked by the Glace Bay Mining Company. At the Roost slope and McLay pit this seam yields a very tender and friable coal, which is probably the most easily and cheaply worked coal in Cape Breton. Nevertheless, it has the reputation of being the best gas-coal in the island, while it also ranks well for domestic purposes.

The Harbor or International seam has been extensively worked by the Glace Bay Mining Company at the Harbor and Sterling pits, and by the International Mining Company at Bridgeport. At both places the coal has given great satisfaction, breaking in fine large blocks, highly esteemed for gas and domestic purposes.

The next seam now worked is the Phelan, which has been more extensively mined than any other in this section. At the old Bridgeport mine, owned by the General Mining Association of London, a considerable amount was worked over thirty years ago. At present it is largely worked at the Reserve mines, owned by the Sydney and Louisburg Coal and Railway Company of London; at Caledonia Colliery, owned by the Caledonia Mining Company; and at the Clyde or Ontario mines, owned by Messrs. Campbell of Halifax. The coal from the Phelan seam turns out well, and gives general satisfaction as a steam and domestic coal at the old Bridgeport mine. The Phelan seam is somewhat undulating, but maintains an average dip of 5°.

The next working seam in descending order is one partially worked at Schooner Pond, and there known as the Ross seam. It was also worked at the Emery mine, under the name of the Emery seam. The coal from the Emery slope gave great satisfaction, and the nature of the roof indicated a good seam for long-wall working. The Emery coal had a splendid reputation for both steam and domestic purposes.

Below the Ross or Emery seam comes the Lorway seam, four feet in thickness, of good, clean coal. This seam has only been worked to a small extent at the Lorway West pit, owned by the Sydney and Louisburg Coal and Railway Company. Unlike any other seam in this section, it shows in the coal very close and numerous cleavages. At the face of the breast it presents a firm, solid appearance, and with careful blasting makes good, large coals; but from its thin cleavage this coal is not adapted for banking during severe winters. In fact it is one of those seams that would prove

most remunerative when worked during the summer months, or the season of navigation only.

Below the Lorway, the next working seam, and the most westerly worked in this section, is the Gardiner, which has been fully proved by the sinking of the Gardiner pit by the Gardiner Coal Mining Company of Montreal.

About 130 feet below the Gardiner, another seam, 5 feet 6 inches thick, has been proved at the outcrop which, from the appearance of the coal, seems well adapted for gas purposes.

Westward of this new Gardiner seam are two small seams, called Clarke's and Martin's, containing very fine coal, but not of sufficient thickness to work profitably in competition with the larger seams. So far as is known, these seams define the western limit of the Glace Bay basin.

No. 4. *The Block House Section.*—Basin No. 4 is separated from No. 3 by an anticlinal, running nearly east and west, and forming the range of hills between Cow Bay and Schooner Pond, over which the road from Schooner Pond to Cow Bay is made through a formidable accumulation of conglomerate boulders. Most of the seams being cut off by the waters of Cow Bay harbor, this basin is limited in extent; nevertheless, it contains coal-seams of a very valuable character. It may be said to be the only basin in the Sydney coal-field that has been thoroughly proved. In the Block House seam, slopes have been driven from the southern outcrop down to the lowest level of the basin and out again (at a greater angle) on the northern outcrop near the anticlinal, and again at a point proving the extent of the basin to the westward of Cow Bay. The coal-measures thus developed in this basin are about 1300 feet, containing seven seams of coal, five of which are more than three feet thick, the highest and most valuable—the Block House seam—being nine feet thick. But unfortunately, in point of surface-area, this is the most limited of the four basins. It is almost entirely covered by the area of the Block House Mining Company.

Geologists have endeavored to identify this basin with that of Glace Bay, but the intervening anticlinal, the positive proof given in the workings of the Block House seam, and the great disparity in the number of working seams in the two basins, practically discourage such an attempt. On the eastern side of Cow Bay Harbor there is a continuation of the seams running through the point of land between Cow Bay and Mira Bay. At False Bay Beach, the most southern point of Cow Bay, is found the Tracey seam. Up to

this time this seam has not been found at any other place in the Sydney coal-field, and in all probability it curves round to the north in conformity to seams in the Block House basin, and is broken off by the anticlinal. On account of its isolated position this seam has not been included in this paper among the seams in the Block House or Cow Bay Basin.

The first seam in descending order is the Block House, which has been worked very extensively by the Block House Mining Company of New York. This seam, like most seams yielding gas coals, is in some parts very friable, but on the whole, it yields coal of an average good appearance, which for some years has been in great demand in New York and Boston as a gas-coal. One strange and singular peculiarity in this seam is, that in many parts of the workings it is found for a distance of ten or twelve yards, thickly mixed with lumps of fire clay. In all cases where this disturbance occurs, the angle of the dip remains the same. The workings in this seam have proved conclusively the basin formation of the district.

The only other seam working in this basin is the McAuley seam; it has been extensively worked by Messrs. Archibald & Co. at the Gowrie Colliery, has been found to be a good domestic coal, and is in good demand in the various provincial markets.

None of the other seams in this section have been proved by working, but their existence, depth, and angle of dip, have all been undoubtedly proved by trial-pits near the several crops.

From the foregoing brief description of the Sydney coal-field, it will be seen that the small island of Cape Breton is destined at some future day to take an important position among the coal-producing countries of the world.

In order to show how capitalists are taking advantage of its mineral wealth, I add a short account of the present working collieries.

*The Sydney Mines.*—These collieries, the pioneers of our Cape Breton coal-trade, are located on the northern side of the Sydney or Spanish River, about one mile inland from Cranberry Head, the northern entrance of the river. This establishment is probably more like an English colliery than any other of the Cape Breton mines. It is owned by the General Mining Association of London, a wealthy English corporation; and the equipments of the colliery are purely English. A stranger arriving at Sydney Bar from England, after a long sea-voyage, and seeing the old-fashioned

wagons on the wharves, would fancy he was near one of the Newcastle collieries. The mining areas of the Association at the Sydney mines comprise sixteen square miles of land-area, and seven square miles of submarine area. Several shafts have been sunk on this property to prove it satisfactorily. The present working establishments consist of what is known as the New Winning, being a pair of shafts about 680 feet deep, to the main seam. The present plant is equal to an output far exceeding any quantity that has been called for up to this time. This colliery is connected with one of the best shipping-places in Cape Breton by a line of railway three miles long, leading from the colliery to North Sydney, on Sydney River, where extensive wharves are erected for the delivery of coal to vessels of large draught. The highest annual shipments from these mines have never exceeded 140,000 tons. The mechanical plant in actual operation for raising and shipping coal, is a pair of English hoisting-engines and one powerful English pumping-engine, besides five English locomotives and a number of other smaller engines for various purposes.

*The Victoria Mines.*—This colliery, owned by the Lingan and Low Point Coal Company, is located on the southern bank of Sydney River, about two miles from Low Point lighthouse, and was established for working submarine areas underlying the entrance of Sydney River. With the exception of that portion of the underground work comprising a pair of slopes passing through the General Mining Association's coal, all the works in this colliery will be under water. The seam has about six feet of clean coal, dipping at an angle of from 40 to 45 degrees. The colliery is connected by four miles of railway with a shipping-place owned by the Company, at South Bar, on Sydney River (opposite North Bar), where wharves are erected in a sheltered position with a good draught of water. The working is by a slope driven at the full dip of the seam, and coal is raised by a pair of 16-inch cylinder (colonial) engines. The water from the mines is forced by Cameron steam-pumps up a separate pumping-slope; for working the railway, one of Neilson's (Glasgow) tank-locomotives is employed. The annual output, so far, has not been large, but it is capable of considerable extension; and with the substantial improvements already made, and the New Winning (further eastward) opened by the present new company, it is destined to become one of our first-class collieries, and assume an important position in the Cape Breton coal-trade of the future.

*The Lingan Mines.*—These mines, five miles further south, are

owned by the General Mining Association of London, and located on the Lingan main seam, in basin No. 2. For thickness of seam, quality of coal, and facility for shipping, this colliery will compare favorably with any others in Cape Breton. A snug little harbor, with about 14 feet draught of water, where coal can be shipped in all kinds of weather, lies about one mile from the slope. The coal is raised from these mines by a slope extending from the outcrop to the full dip of the seam, more than half a mile down under the sea. This colliery is well laid out and capable of doing a large amount of work, if required. Of late years the output has not been large. Wharves are laid out, capable of shipping 800 tons per day, and, if required, the channel into the harbor could be deepened to admit larger vessels. The machinery consists of one powerful double engine for hauling coals and pumping water; and one of Black, Hawthorn & Co.'s locomotives for hauling coal to the wharf. The extent of coal-area at Lingan mines is about sixteen square miles land-area, and eight square miles under the sea.

*The International Mines.*—These are reached from the foregoing by following the shore line and crossing over Lingan Bay. They are owned by the International Coal and Railroad Company of Montreal. In extent of coal-area, these mines are the next largest to those of the General Mining Association of London. They contain four square miles underlain by nearly all the seams in the Glace Bay, or No. 3 basin, many of them, of course, at great depths. The seam at present worked by a shaft 80 feet in depth, is called the Harbor seam of Glace Bay, and is six feet thick. The mines are connected by 12 miles of railway with a splendid shipping-place on the east side of the southern branch of Sydney River, where an extensive pier, 1000 feet long, has been erected for delivering coal to the largest class of vessels, drawing from 16 up to 30 feet of water. The output of these mines has fallen off, on account of the present almost prohibitory duty on coal entering the United States; their highest annual sales have been about 82,000 tons. The machinery comprises one pair of 16-inch engines for hoisting coal, two Cameron steam-pumps for raising water, three capital English locomotives, and the usual number of coal-cars.

*The Glace Bay Mines.*—These are about three miles southeast from the International, and are owned by the Glace Bay Mining Company of Halifax. This is one of the first mining properties opened after the abandonment by the General Mining Association of London of its exclusive mining rights in Nova Scotia. As one of

the first parties taking up areas at that time, this company seems to have been short-sighted in taking so small an area. Its mining rights cover two and a half square miles, underlain by all the seams of the Glace Bay basin, the greatest number of them lying at great depths. The property has been fully developed in the two upper seams, viz., the Hub and the Harbor, to both of which pits have been sunk and extensively worked. The product of both seams has an excellent reputation as a gas-coal, and is largely consumed in the Dominion markets. The Hub seam is one of the highest in the Sydney coal-field, and probably the easiest coal to work. The Glace Bay Company own the whole of the coal in this seam, which is of limited extent; and their present pit and openings are sufficient to work all the coal. The product of this seam is brought to the shipping place by a short line of railway. The Harbor seam is worked by a shaft 300 feet deep. The coal is shipped direct from the tubs coming out of the pit. This Company has great facilities for shipping coal, as it owns the entire rights and privileges of Little Glace Bay harbor, and commands sufficient depth of water to load vessels down to 18 feet draught. Like Lingan and Cow Bay, this harbor is useful for shipping coals later in the season than is practicable at wharves situated on the upper part of Sydney River; but owing to their being on the seaboard, they are all, on the other hand, somewhat more exposed.

The machinery at these mines is all of American manufacture, and much lighter than English mining-machinery. The railway is operated by a small tank-locomotive, made by Neilson of Glasgow.

*Caledonia Colliery.*—This is likewise located on Glace Bay, about one mile from Little Glace Bay harbor. It is owned by the Caledonia Coal and Railway Company of Boston, and comprises two square miles of mining-area, underlain by all the seams in Glace Bay basin, below the Harbor seam. Two pits are sunk to the Phelan seam, which is the only coal mined by this Company. The machinery is first-class, the hoisting engine being of American make and very powerful. The colliery is connected by a railway with the shipping-place, on the south side of Glace Bay harbor. The railway is operated with a small locomotive built by Neilson of Glasgow.

*The Clyde Mines.*—These mines, situated on the south side of Caledonia Harbor, about one mile along the shore, and sometimes called the Ontario Colliery, are owned by the Messrs. Campbell of Halifax, and comprise a splendid property of one and a half square miles. So far, very little work has been done here; the seam has

been opened by a slope to its full dip. The coal worked here is the same as at the Caledonia, being the Phelan seam of 8 feet 6 inches thickness. On account of the small quantity mined, the product of this colliery has not gone much beyond the Halifax market, where it has the reputation of being a good domestic coal. No plant of any consequence has been erected here, there being only a small American hoisting-engine for drawing coals up the slope. The tubs are hauled about a mile to Caledonia Harbor, and discharged directly to vessels, the coal worked during the shipping season being riddled and cleaned in the pit. In proportion to the extent of mining-area, this is probably as fine a property as any in the Sydney coal-field.

*Schooner Pond Colliery.*—This colliery, about two miles further south along the shore, is owned by the Sydney and Louisburg Coal and Railway Company of London, and has a mining-area of two square miles, the principal portion of which is a submarine area, extending from the shore (outside of the Clyde area), some distance under the waters of the Atlantic. Very little has been done here beyond driving a pair of slopes through the coal in the Clyde area, to reach the coals under the sea, owned by the Schooner Pond Company; and, owing to the slight covering of strata, no work of an extensive character has yet been done. The Ross seam, or, as it is now called, the Emery seam, is proved at these mines. The coal is much thicker than in some places at the Emery, but of about the same quality. An excellent 3-feet-gauge railway, 18 miles long, connects this mine with the shipping-port on Sydney River; and its limited product has been shipped there. A portion of Schooner Pond area lies to the northeast (under the sea), and another portion lies to the southwest (under the land) of the Clyde area, and this case seems to be one of those in which an amalgamation of two properties would be immensely beneficial to the owners of both, especially as both could be worked with one plant.

*The Block House Mines.*—These mines, lying beyond the anticlinal from the foregoing, form one of the most extensive of the new collieries. They are owned by the Block House Mining Company of New York, and have a mining-area of two square miles. The seam worked here is the upper seam in No. 4, or Block House basin, and is called the Block House seam. It is not in any other area. The coal is 9 feet thick, and has a reputation as a first-class gas coal. From causes before named, the sales of this colliery have fallen off considerably during the last few years, although an exten-

sive plant has been erected for doing a large work. This area contains also all the other seams of the Block House basin. The Block House coal is worked by both a pit and a pair of slopes. In winter, when the coal is banked, it is all worked by the pit. During the shipping season all the coal is worked by the slope, coming out at the outcrop of the coal in the cliffs. The tubs going direct to the wharf are discharged into the vessels, the coal having been previously riddled and cleaned in the mine. This colliery enjoys a great advantage in having no surface-hauling, vessels being able to moor close alongside the mouth of the slope. But the progress of these works is greatly retarded by the present uncertain character of the shipping-place. When the wind is blowing from certain quarters, no coal can be shipped, owing to a heavy swell coming in from the sea; and gales often cause serious damage to the wharf and shipping property.

*The Gowrie Mines.*—These mines, situated about a mile west of Block House, are owned by the Messrs. Archibald & Co., of North Sydney. This mine works what is termed the McAulay seam in the Block House basin. It is 4 feet 10 inches in thickness. The extent of mining-area held by this Company is two square miles, underlain by all the seams below and including the McAulay.

The coal from this seam works small and makes a considerable amount of slack, but, owing to no blasting powder being used, the coal stands the severe Cape Breton winters. From trials in the American gas-works, this coal has a fair reputation for making gas, but it is principally used as a domestic and steam-coal. A new industry has been started at the Gowrie colliery, in the making of Yeadon's patent fuel from the slack coal. Machinery has been imported from England, and very good-looking bricks of patent fuel are produced. It is hoped that a remunerative business will be done.

The McAulay seam at this colliery is worked by a shaft over 200 feet deep, with an English hoisting-engine. The pit is connected with the shipping-place by about a mile of railway, worked part of the distance by a self-acting incline. The shipping-place here is much safer than at Block House, being inside a strong breakwater, first erected by the enterprising proprietors for the protection of the coal-wharf, but since purchased by the Dominion Government as a general shelter for vessels in Cow Bay. Even with this protection, heavy gales cause great destruction in some seasons.

*The Reserve Colliery.*—Taking a stretch across the country inland,

and again crossing the anticlinal in a northern direction to a distance of about 8 miles, we reach the collieries of the Sydney and Louisburg Coal and Railway Company of London, the first of which is the Reserve colliery, so called from the fact that this area was set apart by the Provincial Government as a mining reservation, to encourage the building of a railway from Sydney for the conveyance of coal. The mining-area is one square mile, and contains all the seams in the Glace Bay basin below Back Pit, or No. 4 seam. This colliery is working the Phelan seam by a pair of diverging slopes, hauling coal out of each. It is well laid out underground for doing a large amount of work, the plant and machinery being of the best and most substantial character. The coal from this seam has been sent to various markets, has been found suitable for gas, and enjoys an excellent reputation for domestic and steam purposes. The slack coal makes a superior coke.

*The Emery Colliery.*—This area, situated about one mile to westward, is also owned by the Sydney and Louisburg Coal and Railway Company. It is proved by workings in the old Emery slope. The Emery seam is about 5 feet thick, and has a loose roof, indicating its suitableness for long-wall working. In the short time the works have been in operation, the coal has gained a first-class reputation for steam purposes; and there is no doubt of its being useful for gas and domestic purposes. The extent of mining-area is two square miles; the mechanical arrangements are of the same style and character as those at the Reserve colliery. The further proposed working of this area is by a slope drift from Reserve seam, cutting the Emery seam at the extreme dip of Emery area. Adjoining this area is the Lorway mining area of two square miles, also owned by the Sydney and Louisburg Coal and Railway Company. One pit has been sunk to a depth of about 70 feet, but nothing has been done in working. All the mines in operation owned by the Sydney and Louisburg Coal and Railway Company are connected with their shipping-place on Sydney River by a private railway of three feet gauge, about twelve miles long. The railway is worked by three English locomotives (two of them are Fairlie twin engines) and the requisite number of coal-cars for doing a large business. A branch railway connects the several colleries with the magnificent harbor of Louisburg. The length of this branch is about twenty-two miles. The shipping-wharves at Sydney and Louisburg, owned by this company, are of the most substantial character and capable of accommodating vessels of great draught.

*Gardiner Colliery.*—This colliery, situated two miles north of Lorway on the shores of the Lingan basin, is owned by the Gardiner Coal Mining Company of Montreal. The mining-area is two square miles, and is underlain by the present working Gardiner seam and another good seam 5 feet 6 inches in thickness, besides the smaller seams known as Clarke's and Martin's seams in Glace Bay, or No. 3 basin. This colliery is the only one having a pit sunk to the extreme dip of the area and having all the coal to work to the rise. No work has been done at this mine for some years. The pit is about 160 feet deep. The machinery is of substantial character, the hoisting-engine having been made by the Messrs. Coupe, of Wigan. The pit is drained by two Cameron steam-pumps, which give great satisfaction. This pit, although not deep, made an immense quantity of water during sinking, and was the first pit sunk on Cape Breton with steam-pumps. The seam worked is about 4 feet 9 inches in thickness, and is a very good steam-coal. The works underground are well laid out, and in case of increased demand could raise a large quantity of coal.

From the foregoing description of the collieries, it will be seen what efforts have been made to utilize these vast stores of coal. It must be borne in mind that previous to 1858 all the minerals (with few exceptions) were owned by a wealthy London corporation, which in that year abandoned nearly all its claims, retaining only those in which it had collieries established, and thus threw into the hands of the Provincial Government an immense area of mining-property. The Government, in order to properly regulate and manage this interest, had to wait for the requisite legislation. Up to the year 1862 the time was spent in prospecting and forming companies for working new properties. After that year the new companies may be said to have got fairly into operation. The following table will show the progress made up to the end of 1884.

From the table, it will be seen that the Cape Breton coal-trade began to expand after the abandonment of the monopoly by the General Mining Association. From 1861 to and including 1865, the production of coal was considerably increased by the demand for provincial coals in the United States markets, consequent on the war; during which time very little coal was carried in United States vessels, owing to the fear of capture by Southern cruisers. Provincial ship-owners as well as coal-owners reaped a good harvest during the war. But this good fortune was not destined to last long. The enormous demands of the United States treasury during

| Name of Colliery. | | 1858 | 1859 | 1860 | 1861 | 1862 | 1863 | 1864 | 1865 | 1866 | 1867 | 1868 | 1869 | 1870 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| Gen. Mining Assn. Previous to 1858.. | 1,819,899 | | | | | | | | | | | | | |
| Sydney Mines..... | ..... | 100,872 | 109,730 | 117,616 | 100,458 | 111,681 | 104,373 | 88,850 | 108,579 | 109,168 | 101,818 | 97,470 | 95,733 | 108,951 |
| Victoria Mines..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 287 | 2,526 | 4,905 | 7,288 |
| Lingan ..... ..... | ..... | 40,042 | 9,299 | 16,298 | 35,300 | 34,203 | 36,059 | 44,372 | 55,108 | 50,686 | 37,150 | 20,736 | 30,377 | 25,744 |
| International..... | ..... | 696 | 1,858 | 1,937 | 1,480 | 2,548 | 4,198 | 6,719 | 16,374 | 10,720 | 20,807 | 5,769 | 7,510 | 10,640 |
| Glace Bay..... | ..... | 469 | 2,373 | 2,297 | 5,544 | 7,780 | 26,724 | 72,077 | 82,247 | 57,905 | 52,026 | 49,719 | 29,615 | 55,783 |
| Caledonia..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 10 | 32 | 9,827 | 22,781 | 27,886 |
| Clyde or Ontario... | ..... | ..... | ..... | ..... | ..... | 30 | 508 | 4,669 | 8,762 | 5,955 | 253 | 815 | 2,279 | 2,125 |
| Schooner Pond..... | ..... | ..... | ..... | ..... | ..... | 370 | 1,360 | 6,337 | 973 | 37 | ..... | ..... | 53 | ..... |
| Block House..... | ..... | ..... | ..... | 3,736 | 7,622 | 16,934 | 15,690 | 70,650 | 91,600 | 89,914 | 71,226 | 36,965 | 73,933 | 40,006 |
| Gowrie..... | ..... | ..... | ..... | ..... | ..... | 2,876 | 15,070 | 28,735 | 43,770 | 33,324 | 38,618 | 47,003 | 49,609 | 52,877 |
| Reserve..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Lorway ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Emery ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Gardiner..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Sundry..... | ..... | ..... | 450 | 1,502 | 3,818 | 8,119 | 6,907 | 5,966 | 6,791 | 1,633 | 1,220 | 2,417 | 437 | 40 |
| Totals..... | 1,819,899 | 142,079 | 123,215 | 143,404 | 154,222 | 184,563 | 207,889 | 328,108 | 414,204 | 359,352 | 323,437 | 273,283 | 317,232 | 311,340 |

| Name of Colliery. | 1871 | 1872 | 1873 | 1874 | 1875 | 1876 | 1877 | 1878 | 1879 | 1880 | 1881 | 1882 | 1883 | 1884 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| Sydney Mines..... | 105,494 | 102,690 | 127,399 | 96,958 | 92,829 | 70,636 | 88,087 | 106,366 | 108,259 | 115,307 | 133,135 | 133,623 | 131,673 | 131,893 |
| Victoria Mines..... | 17,452 | 19,422 | 12,809 | 15,310 | 14,790 | 13,122 | 10,088 | 10,547 | ..... | ..... | ..... | ..... | 154 | 10,408 |
| Lingan..... | 21,940 | 38,504 | 36,720 | 19,697 | 25,673 | 16,533 | 19,130 | 11,527 | 10,220 | 27,897 | 32,376 | 64 | 12,918 | 20,871 |
| International..... | 80,261 | 20,498 | 75,380 | 36,395 | 41,961 | 25,324 | 24,851 | 14,348 | 21,523 | 58,897 | 76,285 | 102,927 | 96,997 | 80,798 |
| Glace Bay..... | 39,515 | 30,715 | 68,199 | 46,585 | 25,797 | 28,962 | 35,376 | 20,429 | 23,279 | 26,400 | 31,611 | 69,049 | 72,677 | 32,753 |
| Caledonia..... | 25,655 | 44,186 | 75,202 | 39,338 | 12,734 | 31,568 | 23,248 | 19,072 | 13,384 | 22,120 | 42,933 | 59,296 | 51,557 | 65,440 |
| Clyde or Ontario..... | 1,830 | 2,600 | 8,394 | 7,070 | 5,426 | 11,288 | 12,389 | 18,831 | 14,322 | 7,852 | 13,410 | 23,366 | 19,522 | 5,715 |
| Schooner Pond..... | ..... | 1,268 | 13,901 | 1,523 | 1,638 | 2,719 | 1,665 | 7,347 | ..... | ..... | ..... | ..... | ..... | ..... |
| Block House..... | 3,768 | 42,748 | 52,571 | 28,897 | 22,154 | 33,220 | 57,577 | 56,759 | 23,519 | 44,517 | 56,849 | 57,437 | 57,791 | 19,585 |
| Gowrie..... | 42,431 | 46,704 | 29,625 | 32,857 | 31,134 | 26,260 | 24,851 | 30,956 | 31,242 | 46,204 | 61,369 | 65,364 | 70,548 | 82,340 |
| Reserve ..... | ..... | 27,802 | 63,929 | 28,769 | 11,752 | 876 | 116 | 7,347 | 17,269 | 31,614 | 68,884 | 74,432 | 104,777 | 86,550 |
| Lorway..... | ..... | 1,478 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Emery..... | ..... | ..... | 28,540 | 22,137 | 6,425 | 655 | 131 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Gardiner..... | ..... | ..... | 9,169 | 20,196 | 11,380 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Sundry..... | ..... | ..... | ..... | 67 | 4,047 | 5,241 | 1,851 | 1,181 | 4,151 | 4,215 | 45 | 125 | ..... | 76 |
| Totals..... | 338,346 | 378,615 | 531,832 | 395,739 | 307,750 | 266,401 | 299,860 | 304,713 | 267,178 | 385,066 | 516,897 | 585,683 | 618,104 | 535,929 |

COMPARATIVE TABULAR STATEMENT OF THE ANALYSIS AND ECONOMIC VALUE OF THE COAL SEAMS IN THE SYDNEY COAL FIELD, CAPE BRETON COUNTY, NOVA SCOTIA.

| Name of Seam. | Name of Mine when Worked. | Thickness of Seam. | | Volatile Matter. | Fixed Carbon. | Ash. | Sulphur. | Cubic feet of Gas per Ton. | Cal. value in lbs. work per lb. Coal. | Authority for Analysis. | Course and Angle of Dip. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ft. | In. | | | | | | | | |
| Sydney Mine..... | Sydney Mines, | 6 | 0 | 32.74 | 61.54 | 5.72 | 3.37 | 8,200 | 8.49 | How & Buist, | N. 60° E. Angle 6° |
| Davy's Head..... | Victoria Mines, | 6 | 6 | 33.70 | 58.40 | 2.90 | ..... | 8,000 | 8.02 | Dawson, | N. 3° W. Angle 40° |
| Lingan Mine..... | Lingan Mines, | 8 | 6 | 30.03 | 66.90 | 3.07 | .77 | 9,600 | 9.07 | How & Buist, | N. 37° E. Angle 12° |
| Harbor Seam..... | International Mines | 5 | 6 | 34.09 | 62.92 | 2.99 | 2.26 | 10,000 | 7.76 | N. Y. Gas Co., | N. 84° E. Angle 5° |
| Harbor Seam..... | Glace Bay Mines, | 5 | 0 | 30.21 | 67.78 | 2 01 | .90 | 10,000 | 9.31 | Harrington, | N. 27° E. Angle 5° |
| Hub Seam..... | Glace Bay Mines, | 9 | 6 | 28.62 | 68.14 | 3.24 | 2.29 | 10,000 | 8.59 | Harrington, | N. 50° E. Angle 5° |
| Phelan Seam..... | Caledonia Mines, | 8 | 0 | 33.00 | 57.37 | 9.63 | ..... | 9,700 | 7.88 | H. Poole, | N. 27° E. Angle 5° |
| Phelan Seam..... | Reserve Mines, | 6 | 0 | 37.26 | 58.39 | 4.35 | 2.06 | 9,500 | 8.02 | Harrington, | N. 58° E. Angle 5° |
| Phelan Seam..... | Clyde Mines, | 8 | 0 | 32.82 | 64.33 | 2.85 | 2.17 | 9,700 | 7.88 | Harrington, | N. 21° E. Angle 5° |
| Ross or Emery..... | Schooner Pd. Mines | 7 | 0 | 38.10 | 58.46 | 3.44 | 1.21 | 9,500 | 8.03 | Harrington, | N. 23° E. Angle 8° |
| Ross or Emery..... | Emery Mines, | 5 | 0 | 38.10 | 58.46 | 3.44 | 1.21 | 9,500 | 8.03 | Harrington, | ..... |
| Gardiner ..... | Gardiner Mines, | 4 | 9 | 34.33 | 61.97 | 3.70 | ..... | 10,700 | 8.51 | Dawson & others, | N. 85° E. Angle 5° |
| Lorway Seam ..... | Lorway W. Pit, | 4 | 0 | 34.84 | 55.98 | 13.28 | 6.27 | 9,500 | 8.02 | Harrington, | N. 51° E. Angle 5° |
| Block House..... | Block House Mines | 9 | 0 | 31.94 | 62.79 | 5.27 | 3.76 | 10,500 | 7.67 | Harrington, | N. 26° E. Angle 6° |
| McAulay..... | Gowrie Mines, | 4 | 10 | 36.25 | 58.05 | 5.70 | 2.34 | 9,000 | 7.97 | Richard & Buist, | N. 18° E. Angle 7° |
| | Average, | .. | ... | 34.07 | 61.45 | 4.77 | 2.39 | 9,560 | 8.21 | ..... | ..... |

the war compelled that government, in 1866, to put a duty of $1.25 per ton on provincial and other coals, and consequently a decrease of shipments is shown from 1865 up to and including 1868. Circumstances having arisen to warrant the United States Government in making, in 1868, a reduction of 50 cents per ton on the duty, the shipments again began to show an improvement; and in 1873 they more than doubled those of 1869. But this increase was assisted by the high price of coal in England, which enabled steamers to buy bunker-coal at a much cheaper rate in Cape Breton. There was also greater demand for Cape Breton coal up the St. Lawrence, from the fact that sailing vessels did not bring so much coal out for ballast as was done in former years. As will be seen from the table this was only a temporary increase; for in 1874 the product of coal was reduced over 230,000 tons, the falling off in the shipments to the United States being 135,599 tons. This was caused, to a certain extent, by the over-stocked markets of 1873, and the sudden financial panic in the fall of that year, which unsettled the commercial machinery on the whole of the Atlantic seaboard.

Much as Cape Breton coal-owners may deplore the loss of trade in the United States in 1874, it is very gratifying to find the demand for coal so much increased in the neighboring provinces as to bring the production nearly up to that of 1865, the year in which over half the product of the Cape Breton mines was shipped to the United States. This shows that in the last nine years there has been a steady annual increase of demand in the provinces for Cape Breton coal. The foregoing tabular statement is intended to show the economic value of the several seams in the Sydney coal-field.

In the foregoing tabular statement the results are obtained from laboratory analyses, except those as to the production of gas, which are given from the reports of the various companies, which have tried the coals for gas purposes. The following figures show that the bituminous coals of this coal-field compare very favorably with coals from other localities:

| | Vol. Matter. | Carbon. | Ash. |
|---|---|---|---|
| Pennsylvania, United States, | 29.50 | 64.40 | 6.10 |
| Virginia, " | 33.68 | 57.76 | 8.56 |
| Indiana, " | 39.00 | 52.00 | 9.00 |
| Illinois, " | 36.59 | 59.47 | 3 94 |
| Iowa, " | 44 00 | 48.50 | 7.50 |
| Missouri, " | 34.06 | 50.81 | 15.13 |
| Newcastle, England, | 37.60 | 57.00 | 5.40 |
| Staffordshire, " | 37.86 | 59.64 | 2.50 |
| Derbyshire, " | 35.10 | 61.65 | 3.25 |

| | Vol. Matter. | Carbon. | Ash. |
|---|---|---|---|
| Yorkshire, England, . . . . | 35.67 | 62 08 | 2.25 |
| North Wales, . . . . | 36.56 | 57.49 | 6.25 |
| Picton, Nova Scotia, . . . . | 29.63 | 56.98 | 13.39 |
| Sydney, Cape Breton, . . . . | 34.07 | 61.43 | 4.50 |

For gas-purposes the Cape Breton coals have given general satisfaction in the United States for a number of years; but owing to import duties are not much in demand in that market.

The season for shipping usually ends in the latter part of December, after which the harbors are closed by ice until the beginning of May, so that consumers using this coal are under the necessity of laying in large stocks to serve over winter, and producers have to bank coal during the winter months at the mines in order to keep the men employed, and to be ready for quick shipments. On both sides there is considerable loss, from depreciation, and in the expense of lifting coal from the bank. Before closing these notes, it may not be out of place to make a few remarks on the system of working and the prices for cutting coal, etc., in this coal-field. As has been shown, all the seams worked crop out at the surface. The existence of full sections of coal-seams in the cliffs enables prospectors to fix on the locality of the crop, and commence operations by driving down a slope on the full dip of the seam. The system of working the coal is principally the bord-and-pillar, or, as it is called here, the "room-and-rib." Rooms are usually driven from 15 to 18 feet wide, with a rib of the same width between, and 66 feet between the cross-cuts. The system of paying for coal-hewing or coal-cutting, as it is called, varies at nearly every colliery; some pay by the ton on all coal not passing through a half-inch riddle (slack being left in the pits); others pay by cubic yard; some by running yard; and others again by the tub. But, in all cases, the holings and shearings are passed over a half-inch riddle, and the slack is left in the pit.

The amount of slack taken out from screening over a half-inch screen is, on an average, about 20 per cent. Taking a six-feet seam as a basis, the cost per ton for cutting (with coal riddled in pit as above) is about 40 cents.

# *THE DISTRIBUTION AND PROPORTIONS OF AMERICAN BLAST-FURNACES.*

BY JOHN BIRKINBINE, PHILADELPHIA, PA.

MUCH has been contributed to the *Transactions* of the Institute concerning the construction and operation of American blast-furnaces; but the following compilation is offered as possibly furnishing additional information upon the general features, dimensions, locations, capacities, etc., of the blast-furnaces of the United States; while, incidentally, the ores upon which they rely are noted in a general way. The paper is presented chiefly as a compilation, and the figures given are selections from most reliable sources, or averages calculated from official statistics, placed for convenient reference, with a view of assisting those who consult the *Transactions* in determining the present relative merits and importance of various sections of the country. The scope of the paper has been restricted to as few topics as possible, and all the details of special plants, or notable outputs have been ignored. While every effort has been made to give correct figures and data, the changes which are constantly taking place in the iron-producing industry, will, undoubtedly, by the time the paper is in print, develop some errors.

It is difficult to determine which of the blast-furnace plants of the country should or should not be considered as upon the active list. A number which have not been in operation for years are still reported as active, some of which will scarcely be put in blast again, and others are handicapped so that they can only operate in times of abnormal profits. It is therefore scarcely probable that there are over 600 blast-furnaces in the United States which can properly be considered as active; but so many considerations affect the various plants, that, it being impossible to determine the exact number, I have relied upon the annual reports presented to the American Iron and Steel Association. Concerning the number of plants which could be stricken from the list, the Secretary of this Association says: "In January last (1885) we enumerated 669 furnaces, which included many stacks which had not been in blast for a very long time, and others which could not be operated except during short periods of exceedingly high prices for pig iron. We have gone over this list very carefully and have eliminated 10 anthracite, 19 bituminous,

and 49 charcoal furnaces, or 78 in all. While most of the furnaces thus dropped have been abandoned, we omit some which are not likely to be operated again, unless prices rise very high and stay high for a time, and even then the majority of them will be found unfit for use without being refitted and practically rebuilt. Making due allowance for 4 furnaces rebuilt in the past six months, the net reduction in the total number of furnaces is 74, which leaves 595 as the number of furnaces in the United States either in blast or likely to blown in when trade shall warrant. To this number will shortly be added several furnaces which are now being rebuilt and others in course of erection which are entirely new." As, however, the purpose of this paper is to discuss the location, equipment, and the operation of the blast-furnaces of the country, the subject will be treated for the present as the published records up to January 1st, 1885, indicated the condition of the industry.

At the close of the year 1884, there were 669 blast-furnaces in the United States reported upon the active list. Of this number, 230 employed charcoal, 220 bituminous coal and coke, and 219 anthracite coal as fuel. During the year, less than one-half of the furnaces were in operation, and their product amounted to 4,589,630 net tons, or 4,097,868 gross tons. To produce this metal, there was consumed 7,213,764 gross tons of domestic ore, and 439,183 gross tons of foreign ore, making a total of 7,652,947 gross tons of ore used, or 1.87 tons of ore per ton of pig-iron. The fuel consumed in the blast-furnaces to smelt this ore was as follows:

| | | | |
|---|---|---|---|
| Coke, | 3,697,275 | gross | tons |
| Anthracite coal, | 1,543,688 | " | " |
| Bituminous coal, | 326,986 | " | " |
| Charcoal, 50,577,153 bushels, equivalent to, | 421,476 | " | " |
| Making a total of, | 5,989,425 | " | " |

(In this estimate 120 bushels of charcoal are assumed as equivalent to one gross ton. This is a little less than 18 pounds per bushel, and is probably as close an approximation as can be made for the country at large.)

In addition to the ore above mentioned, a considerable amount of mill- and forge-cinder was used in our blast-furnaces; and this will probably not fall short of 500,000 net tons. This quantity would bring the average consumption of ore per ton of iron up to about 2 gross tons, but as the amount of mill-cinder used is indefinite, it will be better to base comparisons upon data collected

by the American Iron and Steel Association, published in its *Bulletin*, which shows that, independent of the amount of cinder employed, the State using the richest iron ore was Illinois, where 1.45 tons of ore were required to produce one ton of pig iron. West Virginia follows next with 1.46 tons, then Michigan with 1.57 tons, Missouri and Wisconsin with 1.66 tons. In Ohio, 1.76 tons, and in Pennsylvania, 1.83 tons of ore were required to produce a ton of pig iron. The leanest ore was used in Maryland, where 2.06 tons were necessary for one ton of pig iron. The States showing the richest ores depend almost entirely upon the Lake Superior ores or the specular ores of Missouri for their supply; while Maryland relies almost wholly upon carbonates. The yield of the magnetites of New Jersey shows that State as using 1.9 tons of ore, while New York requires 2.02 tons, per ton of iron made. Pennsylvania shows a higher percentage of ore than would otherwise be the case, on account of the amount of select foreign ore imported. In the Southern States the amount of ore used per ton of iron varies from 2.28 in Virginia to 2.32 in Georgia and Alabama.

The data above referred to show that in smelting the ores in the various States, the average amount of fuel consumed to produce one ton of pig-iron was as follows: anthracite, 1.50 tons in Pennsylvania to 1.61 tons in New York; an average of 1.52 tons. Bituminous coal and coke, 1.30 tons in Illinois to 2.13 tons in Kentucky, an average of 1.36 tons for the whole country. Charcoal, 97 bushels, equal to .81 tons, in Michigan, to 172 bushels, equal to 1.45 tons, in Virginia; an average of 123 bushels, or 1.03 tons per ton of iron for the entire country. In the anthracite districts coke is often mixed with the harder fuel to encourage better driving of the furnace, and as the industry is distributed in the States of New York, New Jersey, and Pennsylvania, with a few establishments in Maryland, there is scarcely sufficient data to form any general comparisons of operation; but in the furnaces using bituminous fuel and charcoal, we do not find that a low fuel consumption necessarily accompanies the smelting of rich ores. Thus, the amount of bituminous fuel employed in Georgia, Alabama, and West Virginia is practically the same, although in the two States first named 2.32 tons of ore are required to make one ton of pig iron, while in the latter State 1.46 tons are demanded, and the coke of Alabama and Georgia is not as good as that generally employed in West Virginia. Similarly, Pennsylvania, Virginia, and Missouri use the same amount of bituminous fuel to produce one ton of pig

iron, although the quantity of ore required is 1.83 tons in Pennsylvania, 2.28 tons in Virginia, and 1.66 tons in Missouri. This may be accounted for in part by remembering the large number of old furnaces in Pennsylvania, as compared with the other States. Ohio, with ores which make a ton of pig iron with 1.76 tons of ore, requires 1.74 tons of fuel, but a considerable portion of the coal used in Ohio cannot be considered as of superior quality.

The distribution and arrangement of the blast-furnaces of the United States is itself a topic which would exhaust the limits of a large paper if an attempt was made to go into detail. Pennsylvania stands first as an iron producing State, followed in order by Ohio, Illinois, New York, Alabama, Michigan, Virginia, and Tennessee, all of which produced in 1884 over 100,000 tons of pig-iron. In the 23 States and one Territory in which pig-iron was produced in 1884, charcoal was used in all but Illinois, New Jersey, West Virginia, Colorado, and Indiana; and in the States of Michigan, Connecticut, Texas, Massachusetts, Oregon, California, and North Carolina, and in Washington Territory, charcoal was the only fuel used. From the data above given, it is evident that the blast-furnaces of the United States are distributed over an extensive area, and employ quite a variety of ores and fuels.

The ores used come from localities even more scattered than the furnaces, and are of all kinds. Starting at the northeastern part of the country, we find that in Maine limonite ore has been used. In northern New York, along Lake Champlain, rich magnetic ores abound; toward the St. Lawrence River, limonites are used; in the centre of the State, fossil ores are mined; while along the boundary of Massachusetts, Connecticut, and New York, both limonites and magnetites are obtained, and a considerable industry has lately been established to develop deposits of carbonates. New Jersey obtains its supply chiefly from its local mines of magnetic ores. In Pennsylvania, both limonites and fossil ores abound through the eastern and central portions, and a considerable quantity of magnetic ore is also obtained from the same localities. The most important single operation is at Cornwall Ore Banks in central Pennsylvania, where over 1000 tons per day are mined from a deposit, estimated to have above ground from 30,000,000 to 40,000,000 tons. In Maryland, limonites and carbonates (the latter existing in pockets or kidneys) are chiefly used, and in Virginia, limonites and magnetites, particularly the former, are the main dependence. North Carolina and eastern Kentucky and Tennessee sustain a few charcoal blast-furnaces upon deposits

of limonite and magnetite. West Virginia has some good ores, but its furnaces rely largely upon ores brought from Lake Superior and from Missouri. In Georgia, and more particularly in Alabama, the contiguity of brown and red hematite ores to coal-deposits or heavily timbered areas, has brought that section into unusual prominence. In Tennessee as in Alabama, there are practically two principal ore districts, which may be described generally as following the north and south courses of the Tennessee river. In the eastern part of the State, where the river flows in a southerly direction, fossil ores abound, and are smelted in coke furnaces, while in the more central portions of the State, where the Tennessee flows northerly, the limonites are plentiful, and are smelted chiefly with charcoal. The same may be said to exist in Alabama, but in this case the line of fossil ores is to the westward of the line of the principal limonite district.

Northeastern Ohio is well supplied with blast-furnaces, but obtains only a small part of its supply from local mines, most of the ore for eastern Ohio and western Pennsylvania being brought from Lake Superior and smelted with Connelsville coke, although a local block coal is found immediately at furnaces which were originally constructed mainly to use this fuel. In central and southern Ohio and in Kentucky raw coal is used to a greater extent than elsewhere in the country, and the dependence of the furnaces is principally upon local carbonate ores mixed at times with Lake Superior and Missouri ores. A group of blast-furnaces, some using raw coal and some depending upon charcoal as fuel, located in southern Ohio and northern Kentucky are generally recognized as the Hanging Rock District. Indiana is deficient in local ore-supplies, and the attempts to establish the industry with the block-coals found in that State cannot be said to have proved advantageous. Illinois is without local ores, and the furnaces are centered chiefly in the northern portion, and obtain their supply from the Lake region, although in the southern districts, along the Mississippi river, plants have been constructed to use the rich specular ores of Missouri. These ores also form the basis of the iron industry in Missouri, and are obtained from the noted deposits of Pilot Knob and Iron Mountain and from the beds of softer hematites in the central part of the State; these latter, however, being chiefly smelted with charcoal.

Texas has a small iron-producing capacity, relying upon limonite ores, and charcoal for fuel. Michigan uses charcoal alone as fuel, and smelts Lake Superior ores, which, owing to their richness, permit of remarkably good work and large yields. Wisconsin, while

depending principally upon Lake Superior ores, also has some local supplies of hematite, one peculiar deposit in the eastern part of the State being known as "Flax-seed" ore from its close resemblance in size and appearance to that grain.

Minnesota, Colorado, California, Oregon, and Washington Territory have each one furnace-plant, all using charcoal except that in Colorado; and deposits of good ores are claimed to exist in all of them. The only furnace in Washington Territory depends on ores brought from British North America.

The sizes of the blast-furnaces in the United States are scarcely less varied than the ores they use; and the method of construction and the mode of equipment exhibit fully as many differences as the structures themselves. One remarkable feature, however, is the pertinacity with which various districts, although close together, maintain special features, either of construction or equipment, by which they may be readily recognized.

The following tables will indicate the number, the variations in size, and what might be considered an average size for the furnaces using the different fuels in most of the States, and in the whole country. The Census Statistics of iron and steel for 1880 exhibit, by a series of maps, the location of iron manufacture and production, and give at a glance the general position and the relative importance of various sections of the country. Taking the blast-furnaces, I find that in most cases, convenience of supplies, ore, flux, and fuel, or the carrying of their product, have been the guiding causes in determining the location; and, generally speaking, the existence of iron-ores in the immediate vicinity has predominated in selecting the location of the blast-furnaces, particularly those of the older plants; but, in many cases, the works have been placed far from their ore-supplies, and more convenient to fuel or market.

In the former class, viz: those located close to ore-supplies, and distant from sources of fuel—may be mentioned, practically, all of the blast-furnaces using mineral fuel in the New England States and in New York.

The furnaces at Pittsburgh, and in western Pennsylvania generally, have cheap fuel convenient; some have a partial supply of local ores, but most of them obtain their ore supply from distant points.

In eastern Pennsylvania, southwest Virginia, Colorado, Tennessee, and Alabama, fuel and ores both abound, and the furnaces may be classed as occupying middle ground as to transportation facilities.

The furnaces about the larger cities of New York, Pennsylvania,

Ohio, Illinois, and Missouri have mainly the convenience of market and competitive transportation of stock for a basis of location. Some of them possess certain advantages as to reception of raw materials, but their position must be considered as available chiefly on account of the market and railroad features. In general terms, we might say that, heretofore, the furnaces located for a market for their product have been less successful than those placed nearer ores or nearer fuel; but some new plants, situated at good market centers, to which ores, fuel, and flux must be carried long distances, appear to produce most satisfactory results.

The charcoal furnaces of the United States are mostly placed close to, or within, cheap transportation of ore-supplies, and the accessibility of sufficient fuel is also considered in selecting a site. Some of the charcoal furnaces, such as those in Michigan, Wisconsin, and Washington Territory, have to transport their ores to locations where fuel is abundant, but, with few exceptions, the location of the charcoal furnaces may be considered as being placed close to their ore- and fuel-supplies, practically independent of market-conveniences, and often of transportation-facilities.

The charcoal furnaces about Baltimore are favored with cheap fuel, on account of having water-transportation from extensive areas of timber. They are convenient to market, but suffer on account of costly ores.

As a rule, we have not been as careful as circumstances warrant in selecting locations for blast-furnaces, and our iron-producing industry probably suffers fully as much from bad location as it does from inferior construction, or from want of good management.

There are a few active blast-furnaces which have been apparently injudiciously located, for which an excuse can be found in their connection with some other business enterprise, such as the development of a large tract of land owned by the parties operating the furnace; but generally the plants which are defective in location are idle, and those in blast now are favored either by excellent management, modern equipment, or superior location.

The annexed table, compiled from the Directory of the American Iron and Steel Association, has been prepared to illustrate the range, dimensions, and capacities of furnaces in various parts of the country using the different fuels. The table is arranged, first, in the order of the kind of fuel used, three classes only being recognized, namely, those using anthracite coal, or anthracite mixed with coke; those using bituminous fuel, embracing furnaces depend-

ing upon coke, raw bituminous coal, or raw coal mixed with coke; and furnaces which are operated by charcoal. The table represents the maximum and minimum diameters of bosh, and the maximum and minimum height of furnaces at the time it was prepared. In connection with the maxima and minima, average dimensions are presented, not as being absolute, but merely as indicating in a general way the preponderance of size. The maximum height and maximum diameter, or minimum height and minimum diameter, are not necessarily associated in one furnace, but the table has been made to show at a glance the general and the average proportions of the blast-furnaces in each district or State:

PROPORTIONS OF AMERICAN BLAST FURNACES USING COKE OR BITUMINOUS COAL AS FUEL.

| States and Districts. | Number of stacks. | Reported annual capacity. Net tons. | Dimensions of furnaces. | | | | | | | | | | Average capacity per furnace, net tons. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Height. | | | | | | Diameter at bosh. | | | | |
| | | | Maximum. | | Minimum. | | Average. | | Maximum. | | Minimum. | | Average. | | |
| | | | Ft | In | Ft | In | Ft | In | Ft | In | Ft | In | Ft | In | |
| Pennsylvania: | | | | | | | | | | | | | | | |
| Shenango Valley... | 27 | 567,000 | 78 | 0 | 46 | 0 | 59 | 1 | 20 | 0 | 9 | 0 | 13 | 9 | 21,000 |
| Allegheny Co..... | 16 | 713,500 | 85 | 0 | 45 | 0 | 70 | 8 | 20 | 0 | 12 | 0 | 17 | 6 | 44,600 |
| Miscellaneous..... | 39 | 619,700 | 78 | 0 | 28 | 0 | 56 | 2 | 19 | 6 | 8 | 6 | 13 | 6 | 15,900 |
| Total for State... | 82 | 1,900,200 | 85 | 0 | 28 | 0 | 62 | 0 | 20 | 0 | 8 | 6 | 14 | 4 | 23,200 |
| New York..... | 1 | 18,000 | ... | | ... | | 65 | 0 | ... | | ... | | 13 | 0 | 18,000 |
| Maryland ..... | 1 | 8,000 | ... | | ... | | 50 | 0 | ... | | ... | | 11 | 0 | 8,000 |
| Virginia..... | 12 | 226,000 | 85 | 0 | 35 | 0 | 59 | 9 | 20 | 0 | 9 | 0 | 13 | 8 | 18,800 |
| Alabama..... | 10 | 211,000 | 75 | 0 | 50 | 0 | 63 | 4 | 18 | 0 | 10 | 6 | 14 | 8 | 21,100 |
| Georgia..... | 1 | 30,000 | ... | | ... | | 63 | 0 | ... | | ... | | 16 | 0 | 30,000 |
| West Virginia..... | 7 | 127,000 | 75 | 0 | 50 | 0 | 60 | 7 | 17 | 0 | 10 | 6 | 14 | 5 | 18,100 |
| Kentucky..... | 3 | 57,000 | 68 | 0 | 62 | 0 | 65 | 0 | 16 | 0 | 15 | 6 | 15 | 10 | 19,000 |
| Tennessee..... | 8 | 217,500 | 70 | 0 | 61 | 0 | 66 | 2 | 18 | 0 | 13 | 6 | 15 | 10 | 27,200 |
| Ohio: | | | | | | | | | | | | | | | |
| Hanging Rock Dis. | 15 | 164,300 | 86 | 0 | 47 | 0 | 58 | 2 | 18 | 0 | 11 | 0 | 14 | 3 | 11,000 |
| Mahoning Valley.. | 18 | 473,000 | 80 | 0 | 45 | 0 | 65 | 2 | 18 | 0 | 10 | 6 | 15 | 4 | 26,300 |
| Hocking Valley.... | 14 | 209,100 | 64 | 0 | 44 | 0 | 55 | 1 | 16 | 0 | 12 | 0 | 14 | 3 | 15,000 |
| Miscellaneous..... | 17 | 442,000 | 80 | 0 | 51 | 0 | 63 | 0 | 20 | 0 | 13 | 0 | 15 | 2 | 26,000 |
| Total for State... | 64 | 1,288,400 | 86 | 0 | 44 | 0 | 60 | 9 | 20 | 0 | 10 | 6 | 14 | 9 | 20,100 |
| Indiana..... | 2 | 18,000 | 60 | 0 | 52 | 0 | ... | | 13 | 0 | 12 | 0 | ... | | 9,000 |
| Illinois..... | 16 | 667,000 | 75 | 0 | 60 | 0 | 69 | 3 | 21 | 0 | 14 | 6 | 18 | 0 | 41,700 |
| Missouri..... | 8 | 168,000 | 75 | 0 | 56 | 0 | 60 | 6 | 20 | 0 | 14 | 0 | 15 | 8 | 21,000 |
| Michigan..... | 2 | 30,000 | 63 | 0 | 60 | 0 | ... | | 17 | 0 | 12 | 0 | ... | | 15,000 |
| Wisconsin..... | 3 | 77,000 | 66 | 0 | 55 | 0 | 62 | 4 | 17 | 0 | 15 | 0 | 16 | 4 | 25,700 |
| Colorado..... | 1 | 24,000 | ... | | ... | | 65 | 0 | ... | | ... | | 15 | 0 | 24,000 |
| United States..... | 221 | 5,067,100 | 86 | 0 | 28 | 0 | 66 | 0 | 21 | 0 | 8 | 6 | 14 | 11 | 22,900 |

PROPORTIONS OF AMERICAN BLAST FURNACES USING ANTHRACITE COAL AS FUEL.

| States and Districts. | Number of stacks. | Reported annual capacity. Net tons. | Dimensions of furnaces. | | | | | | | | | | Average capacity per furnace, net tons. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Height. | | | | | | Diameter at bosh. | | | | |
| | | | Maximum. | | Minimum. | | Average. | | Maximum. | | Minimum. | | Average. | | |
| | | | Ft | In | Ft | In | Ft | In | Ft | In | Ft | In | Ft | In | |
| Massachusetts.t..... | 1 | 10,000 | ... | | ... | | 50 | 0 | ... | | ... | | 14 | 0 | 10,000 |
| New York..... | 40 | 556,150 | 71 | 0 | 40 | 0 | 56 | 6 | 18 | 0 | 2 | 0 | 15 | 0 | 13,900 |
| New Jersey..... | 20 | 281,200 | 80 | 0 | 20 | 0 | 54 | 9 | 20 | 6 | 7 | 0 | 14 | 6 | 14,000 |
| Pennsylvania: | | | | | | | | | | | | | | | |
| Lehigh Valley..... | 51 | 775,000 | 75 | 0 | 33 | 0 | 61 | 6 | 19 | 0 | 8 | 6 | 16 | 4 | 15,200 |
| Schuylkill Valley.. | 44 | 530,600 | 80 | 0 | 40 | 0 | 55 | 3 | 18 | 0 | 11 | 0 | 14 | 4 | 12,000 |
| Upper Susqueh'na. | 23 | 284,700 | 70 | 0 | 36 | 0 | 51 | 9 | 20 | 6 | 10 | 0 | 14 | 9 | 12,400 |
| Lower " | 37 | 599,432 | 80 | 0 | 33 | 0 | 52 | 3 | 20 | 0 | 9 | 6 | 13 | 5 | 16,200 |
| Total for State... | 155 | 2,189,732 | 80 | 0 | 33 | 0 | 56 | 1 | 20 | 6 | 8 | 6 | 14 | 10 | 14,100 |
| Maryland..... | 5 | 37,000 | 53 | 0 | 32 | 0 | 42 | 2 | 15 | 0 | 11 | 4 | 12 | 6 | 7,400 |
| United States..... | 221 | 3,074,082 | 80 | 0 | 20 | 0 | 55 | 8 | 20 | 6 | 7 | 0 | 14 | 10 | 13,900 |

PROPORTIONS OF AMERICAN BLAST FURNACES USING CHARCOAL AS FUEL.

| States and Districts. | Number of stacks. | Reported annual capacity. Net tons. | Dimensions of furnaces. | | | | | | | | | | Average capacity per furnace, net tons. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Height. | | | | | | Diameter at bosh. | | | | |
| | | | Maximum. | | Minimum. | | Average. | | Maximum. | | Minimum. | | Average. | | |
| | | | Ft | In | Ft | In | Ft | In | Ft | In | Ft | In | Ft | In | |
| Maine..... | 1 | 5,000 | ... | | ... | | 55 | 0 | ... | | ... | | 9 | 6 | 5,000 |
| Vermont..... | 1 | 4,000 | ... | | ... | | 40 | 0 | ... | | ... | | 10 | 0 | 4,000 |
| Massachusetts..... | 4 | 14,500 | 33 | 0 | 32 | 0 | 32 | 3 | 9 | 6 | 9 | 0 | 9 | 2 | 3,600 |
| Connecticut..... | 9 | 35,000 | 40 | 0 | 31 | 0 | 34 | 1 | 9 | 6 | 9 | 0 | 9 | 1 | 3,900 |
| New York..... | 14 | 70,000 | 55 | 0 | 30 | 0 | 38 | 4 | 10 | 6 | 8 | 6 | 9 | 4 | 5,000 |
| Pennsylvania..... | 32 | 91,590 | 54 | 0 | 28 | 0 | 33 | 1 | 10 | 8 | 7 | 0 | 8 | 6 | 2,900 |
| Maryland..... | 14 | 57,200 | 52 | 0 | 28 | 0 | 38 | 9 | 11 | 0 | 6 | 6 | 8 | 9 | 4,100 |
| Virginia..... | 31 | 109,225 | 47 | 0 | 25 | 0 | 34 | 3 | 12 | 0 | 7 | 6 | 9 | 1 | 3,500 |
| North Carolina..... | 6 | 16,800 | 54 | 0 | 30 | 0 | 40 | 6 | 10 | 0 | 6 | 0 | 8 | 6 | 2,800 |
| Georgia..... | 6 | 25,250 | 60 | 0 | 30 | 0 | 42 | 4 | 12 | 8 | 7 | 0 | 8 | 9 | 4,200 |
| Alabama..... | 12 | 96,200 | 62 | 0 | 40 | 0 | 52 | 0 | 14 | 0 | 8 | 8 | 11 | 0 | 8,000 |
| Texas..... | 2 | 7,000 | 55 | 0 | 55 | 0 | ... | | 9 | 6 | 8 | 6 | 9 | 3 | 3,500 |
| West Virginia..... | 6 | 21,095 | 48 | 0 | 30 | 0 | 38 | 0 | 13 | 0 | 6 | 0 | 10 | 9 | 3,500 |
| Kentucky..... | 14 | 59,040 | 50 | 0 | 17 | 0 | 39 | 6 | 14 | 0 | 6 | 0 | 9 | 8 | 4,200 |
| Tennessee..... | 9 | 42,460 | 65 | 0 | 32 | 0 | 40 | 10 | 12 | 0 | 8 | 0 | 10 | 6 | 4,700 |
| Ohio ..... | 21 | 91,400 | 42 | 0 | 32 | 0 | 36 | 8 | 12 | 0 | 8 | 6 | 13 | 0 | 4,300 |
| Indiana..... | 1 | 7,000 | ... | | ... | | 60 | 0 | ... | | ... | | 10 | 1 | 7,000 |
| Missouri..... | 9 | 97,125 | 60 | 0 | 34 | 0 | 45 | 9 | 11 | 0 | 9 | 2 | 9 | 8 | 10,800 |
| Michigan..... | 26 | 347,115 | 56 | 0 | 40 | 0 | 46 | 9 | 11 | 4 | 8 | 0 | 9 | 2 | 13,400 |
| Wisconsin..... | 11 | 89,000 | 52 | 0 | 27 | 0 | 42 | 1 | 10 | 6 | 7 | 9 | 10 | 0 | 8,000 |
| Minnesota..... | 1 | 10,000 | ... | | ... | | 45 | 0 | ... | | ... | | 8 | 0 | 10,000 |
| Utah..... | 1 | 4,000 | ... | | ... | | 45 | 0 | ... | | ... | | 10 | 0 | 4,000 |
| California..... | 1 | 12,000 | ... | | ... | | 45 | 0 | ... | | ... | | 10 | 0 | 12,000 |
| Oregon..... | 1 | 8,000 | ... | | ... | | 42 | 0 | ... | | ... | | 11 | 0 | 8,000 |
| Washington..... | 1 | 10,000 | ... | | ... | | 52 | 0 | ... | | ... | | ... | | 10,000 |
| United States..... | 234 | 1,330,000 | 65 | 0 | 17 | 0 | 39 | 7 | 14 | 0 | 6 | 0 | 9 | 6 | 5,680 |

Total number of blast-furnace stacks in the United States using as fuel,

| | |
|---|---|
| Anthracite coal, | 221 |
| Coke and bituminous coal, | 221 |
| Charcoal, | 234 |
| Grand total, | 676 |

These tables show two anthracite, one bituminous and four charcoal furnaces more than the Annual Report of the American Iron and Steel Association, owing to the fact that the Directory and Report are not contemporaneous by a few months.

Aggregate annual capacity of blast-furnaces in the United States using as fuel,

| | |
|---|---|
| Anthracite coal, | 3,074,082 net tons. |
| Coke and bituminous coal, | 5,067,100 " |
| Charcoal, | 1,330,000 " |
| Total annual capacity, | 9,471,182 " |

The present range of dimensions is as follows: maximum height of furnaces, 86 feet; minimum height of furnaces, 17 feet.

Maximum bosh diameter of furnaces, 21 feet; minimum bosh diameter of furnaces, 6 feet.

Average capacity of all furnaces in the United States, 14,011 net tons annually.

The difference between the capacities and the output of our blast-furnaces is often misunderstood by those who discuss iron statistics, and the relation between the total number of furnaces and the number in blast seems to be but imperfectly appreciated. The *Iron Age* has, since September, 1876, published periodically returns of the number of furnaces, active and idle, and the Secretary of the American Iron and Steel Association, in his annual reports, has covered the same ground since 1872. The data collected by these two sources seldom agree exactly, for the information is not often obtained on the same dates and from the same sources. The statistics published by the American Iron and Steel Association are issued at greater intervals than those of the *Iron Age*, more time can be devoted to revision, and the information coming directly from each individual plant is probably more exact than it is possible for a periodical to secure from staff-correspondents in time for prompt publication.

The January reports generally show a maximum number of all the blast-furnaces active; April ordinarily exhibits the largest

number of bituminous furnaces in blast; the greatest activity in anthracite furnaces has been noted by the January reports; the maximum number of charcoal furnaces are in operation chiefly when the October and January returns are made; and the minimum number is generally in April. The latter fact is owing to the practice which many charcoal furnaces still pursue of blowing out early in each year when the stock of charcoal is exhausted; as in most parts of the country where charcoal pig-iron is produced charcoal cannot be made in meilers before May, a large proportion of the furnaces are idle when the April returns are collected.

To more fully understand the proportion of active and idle furnaces, the accompanying table has been prepared, showing the percentage of the blast-furnaces of the United States, arranged according to the fuel used, which were active at the dates named:

The reports from the two authorities are placed in parallel columns, and wherever the data have been approximately contemporaneous they are on the same horizontal line. Wherever blank spaces are left there were no reports made at the time noted.

From the Table of percentages we learn that at no time since 1873 have over 63.7 per cent. of all the furnaces in the country been reported as in blast, and the proportion of active furnaces has been as low as 30 per cent. of the whole. The largest percentage of active furnaces returned was 82.1, as shown by the record of anthracite furnaces in April, 1880, and the least proportion of anthracite furnaces in blast was 31.1 per cent., in September, 1876. The bituminous furnaces show less variation than those using anthracite fuel, the maximum percentage of the bituminous furnaces being 70.7, in April, 1881, and the minimum 36.3, in September, 1876. The returns for December 31, 1873, show 68.1 per cent. of the charcoal furnaces in operation, and those for April, 1877, exhibit but 20.2 per cent. in blast.

This analysis may surprise some, for few will surmise that in the past twelve years there have at no time been two-thirds of all the blast-furnaces in the country in operation; that the average proportion of active furnaces has been greater in those using anthracite than in those employing bituminous fuel or charcoal, and that, except in the years 1873 and 1874, and from October, 1880, to October, 1882, less than one-half of the charcoal furnaces have been reported in operation at one time. The difficulty of obtaining reports from some charcoal furnaces may partially account for the latter statement.

PERCENTAGES OF WHOLE NUMBER OF BLAST FURNACES WHICH WERE IN BLAST AT VARIOUS DATES:

| Year. | Date. | From *Iron Age* Quarterly Returns. Charcoal. | Anthracite. | Bituminous. | All Furnaces. | From Annual Reports of the American Iron and Steel Association. Charcoal. | Anthracite. | Bituminous. | All Furnaces. |
|---|---|---|---|---|---|---|---|---|---|
| 1873 | December 31..... | ..... | ..... | ..... | ..... | **68.1** | 66.1 | 48.5 | 62.4 |
| 1874 | December 31..... | ..... | ..... | ..... | ..... | 51.8 | 60 3 | 44.7 | 52.6 |
| 1875 | December 31..... | ..... | ..... | ..... | ..... | 33.8 | 44.4 | 47.3 | 41.09 |
| 1876 | September 1..... | 24.5 | ***31.1*** | ***36.3*** | ***30.0*** | | | | |
| 1877 | January 1 ..... | 25.6 | 39.0 | 40.5 | 34.1 | 26.0 | 37.2 | 37.8 | 33.0 |
| | April 1..... | ***20.2*** | 36.6 | 38.5 | 30.7 | | | | |
| | July 1..... | 32.2 | 38.4 | 40.8 | 36.7 | | | | |
| | October 1..... | 33.2 | 38.0 | ***36.3*** | 35.6 | | | | |
| 1878 | January 1..... | 29.1 | 43.3 | 39.4 | 36.7 | 29.0 | 44.5 | 41.3 | 37.7 |
| | April 1..... | 22.2 | 42.9 | 43.7 | 35.3 | | | | |
| | July 1..... | 23.8 | 42.2 | 41.0 | 34.8 | | | | |
| | October 1..... | 30.5 | 39.4 | 37.5 | 35.4 | | | | |
| 1879 | January 1..... | 29.9 | 41.7 | 40.0 | 36.7 | 33.0 | 42.3 | 40.3 | 38.2 |
| | April 1 ..... | 25.7 | 38.6 | 38.3 | 33.8 | | | | |
| | July 1..... | 31.1 | 43.9 | 47.0 | 40.0 | | | | |
| | October 1 ..... | 37.4 | 55.6 | 55.4 | 48.7 | | | | |
| 1880 | January 1..... | 38.4 | 70.8 | 61.1 | 56.3 | 38.7 | 70.7 | 60.8 | 55.6 |
| | April 1..... | 39.2 | **82.1** | 67.9 | 61.9 | | | | |
| | July 1..... | 48.5 | 70.1 | 51.3 | 56.4 | | | | |
| | October 1..... | 56.0 | 59.8 | 58.4 | 58.0 | | | | |
| 1881 | January 1..... | 58.1 | 68.0 | 65.9 | **63.7** | 57.6 | 68.5 | 65.7 | 63.6 |
| | April 1..... | 50.5 | 66.5 | **70.7** | 61.8 | | | | |
| | July 1..... | 53.2 | 61.8 | 65.1 | 59.6 | | | | |
| | October 1..... | 55.4 | 62.9 | 60.6 | 59.4 | | | | |
| 1882 | January 1..... | 56.1 | 71.6 | 64.5 | 63.6 | 55.1 | 71.7 | 65.7 | 63.5 |
| | April 1..... | 57.8 | 74.1 | 66.9 | 61.5 | | | | |
| | July 1..... | 53.7 | 69.4 | 52.1 | 58.2 | | | | |
| | October 1..... | 61.9 | 68.5 | 53.5 | 61.2 | | | | |
| 1883 | January 1..... | 48.2 | 72.5 | 60 8 | 60.1 | 51.1 | 71.5 | 60.4 | 60.7 |
| | April 1..... | 38.4 | 66.6 | 53.7 | 52.5 | | | | |
| | July 1..... | 43.7 | 53 6 | 48.0 | 48.3 | | | | |
| | October 1..... | 41.1 | 52.5 | 50.6 | 47.8 | | | | |
| 1884 | January 1..... | 31.0 | 47.1 | 44.4 | 40.6 | 35.0 | 53.1 | 47.6 | 44.9 |
| | April..... | 24.7 | 46.3 | 44.0 | 37.9 | | | | |
| | July 1..... | 31.8 | 43.7 | 43.3 | 39.4 | | | | |
| | October 1..... | 29.5 | 37.9 | 35.1 | 34.1 | | | | |
| 1885 | January 1..... | 29.4 | 38.2 | 36.6 | 34 7 | 2.87 | 38.4 | 39.1 | 35.3 |
| | April 1..... | 20.7 | 36.7 | 40.4 | 32.4 | | | | |
| | July 1..... | 21.4 | 36.5 | 41.1 | 32.8 | | | | |
| | October 1 ..... | 27.0 | 34.2 | 39.3 | 33.5 | | | | |

Minima in *Italics*, maxima in **full-faced** figures.

BLAST-FURNACE CAPACITY, FROM "IRON AGE" QUARTERLY REPORTS.

| Year. | Date. | Capacity of Charcoal Furnaces in Blast. Tons. | Capacity of Anthracite Furnaces in Blast. Tons. | Capacity of Bituminous Furnaces in Blast. Tons. |
|---|---|---|---|---|
| 1877 | January | 6,330 | 16,460 | 21,660 |
| | April | 5,025 | 18,240 | 19,875 |
| | July | 7,730 | 17,442 | 20,660 |
| | October | 7,887 | 17.067 | 19,670 |
| | Average per week | 6,743 | 17,302½ | 20,466¼ |
| 1878 | January | 6,624 | 21,040 | 22,923 |
| | April | 5,001 | 19,410 | 23,644 |
| | July | 5,420 | 19,315 | 21,735 |
| | October | 7,079 | 17,660 | 18,360 |
| | Average per week | 6,031 | 19,356¼ | 21,915½ |
| 1879 | January | 6,623 | 20,669 | 23,326 |
| | April | 6,256 | 19,964 | 25,263 |
| | July | 7,420 | 21 032 | 28,458 |
| | October | 9,119 | 29,399 | 32,873 |
| | Average per week | 7,354½ | 22,763½ | 27,480 |
| 1880 | January | 9,013 | 35,267 | 37,342 |
| | April | 8,842 | 40,096 | 39,472 |
| | July | 11,875 | 36,189 | 33,156 |
| | October | 13,988 | 29,851 | 35,790 |
| | Average per week | 10,929¼ | 35,350¾ | 36,440 |
| 1881 | January | 14,708 | 34,845 | 45,438 |
| | April | 13,505 | 35,089 | 48,410 |
| | July | 14,596 | 33,313 | 48,796 |
| | October | 15,009 | 33,224 | 45,515 |
| | Average per week | 14,454½ | 34.117¾ | 47,039¾ |
| 1882 | January | 15,186 | 38,108 | 48,658 |
| | April | 13,596 | 38,566 | 52.027 |
| | July | 15,875 | 36,715 | 40,431 |
| | October | 16,455 | 36,878 | 43,723 |
| | Average per week | 15,277¾ | 37,566¾ | 46.209¾ |
| 1883 | January | 13,700 | 39,340 | 53,144 |
| | April | 11,032 | 37,216 | 48,201 |
| | July | 12.413 | 30,109 | 49,966 |
| | October | 10,686 | 29,969 | 50,452 |
| | Average per week | 11.957¾ | 34.158½ | 50.440¾ |
| 1884 | January | 8,936 | 28,824 | 45,365 |
| | April | 8,713 | 27,612 | 49,236 |
| | July | 10,280 | 26.949 | 47,630 |
| | October | 8,669 | 23,539 | 40,410 |
| | Average per week | 9,149½ | 26,731 | 45.660¼ |
| 1885 | January | 8,371 | 21,564 | 36,812 |
| | April | 7,481 | 21,704 | 45.655 |
| | July | 7,692 | 20,444 | 43.943 |
| | October | 8,056 | 20,318 | 43,234 |
| | Average per week | 7,900 | 21,007½ | 42,411 |

The foregoing statement of blast-furnace capacity shows the estimated output of the furnaces of the several classes at dates corresponding with those given in the Tables which were published in the *Iron Age*. While the total quantities have corresponded remarkably with the full returns published by the American Iron and Steel Association, there has been a divergence where the outputs of the various kinds of pig-iron are considered, and the quantity credited to the charcoal blast-furnaces is somewhat in excess of what was actually produced by them.

To estimate the aggregate furnace-capacity of the country, it would not be proper to divide the output of our blast-furnaces, in any one year, by the average percentage of active furnaces in that year, and multiply the quotient by the total number of stacks; because many reported out of blast are handicapped by situation, size, equipment, or supplies, and go out of blast at times when more fortunate plants can operate successfully. There are always a considerable number of blast-furnaces being repaired or rebuilt; scaffolds, fires, chills, explosions, bad management, scarcity of fuel or ores, financial troubles, and other causes, are constantly occurring to withdraw furnaces from the active list, so that it is doubtful if, under especially favorable circumstances, the country could produce 75 per cent. of the total calculated blast-furnace capacity in any year. The percentages above given show that the average activity is scarcely 50 per cent. of the total number of blast-furnaces.

The character of blast-furnace structures cannot, in the limits of this paper, be discussed; but the variety is great, embracing both the crudest designs and the triumphs of modern engineering. Furnaces are to-day considered on the active list which consist of stone stacks, lined with shale and sandstone, blown with cold blast, through one open tuyere, the blast being supplied from wooden blowing-tubs, connected with a water-wheel, their product averaging from four to six tons per day. Modern plants, making over three hundred tons per day, with equipment of powerful steam-blowing machinery, hot-blast stoves, etc., furnish the other extreme; and between these two are the large majority of American blast-furnaces. Fully seventy-five charcoal blast-furnaces employ cold-blast, and the number of furnaces which are operated with open tops, exceeds one hundred. Although modern practice has been in favor of stacks formed of iron shells supported on columns, nearly one-half of the stacks herein enumerated are in whole or in part stone or brick structures, and one-fourth are what is known as "bank-

furnaces," that is, they are placed against a hillside so as to receive the stock at or near tunnel-head level.

The remodeling of old plants and additions to equipment have caused many furnaces to occupy debatable ground as to character of structure, but without considering the details of arrangement, the above summary will be found close to the facts as they exist at this date. Reconstructions or new plants will decrease the proportion of older arrangements; but many will continue, by reason of local surroundings, to be ranked as named.

The amount of pig-iron produced in the United States, with different fuels, and the total production for thirty-one years has been as follows:

| Years. | Net Tons of 2,000 Pounds. | | | |
|---|---|---|---|---|
| | Anthracite. | Charcoal. | Bituminous. | Total. |
| 1854 | 339,435 | 342,298 | 54,485 | 736,218 |
| 1855 | 381,866 | 339,922 | 62,390 | 784,178 |
| 1856 | 443,113 | 370,470 | 69,554 | 883,137 |
| 1857 | 390,385 | 330,321 | 77,451 | 798,157 |
| 1858 | 361,430 | 285,313 | 58,351 | 705,094 |
| 1859 | 471,745 | 284,041 | 84,841 | 840,627 |
| 1860 | 519,211 | 278,331 | 122,228 | 919,770 |
| 1861 | 409,229 | 195,278 | 127,037 | 761,544 |
| 1862 | 470,315 | 186,660 | 130,687 | 787,662 |
| 1863 | 577,638 | 212,005 | 157,961 | 947,604 |
| 1864 | 684,018 | 241,853 | 210,125 | 1,135,996 |
| 1865 | 479,558 | 262,342 | 189,682 | 931,582 |
| 1866 | 749,367 | 332,580 | 268,396 | 1,350,343 |
| 1867 | 798,638 | 344,341 | 318,647 | 1,461,626 |
| 1868 | 893,000 | 370,000 | 340,000 | 1,603,000 |
| 1869 | 971,150 | 392,150 | 553,341 | 1,916,641 |
| 1870 | 930,000 | 365,000 | 570,000 | 1,860,000 |
| 1871 | 956,608 | 385,000 | 570,000 | 1,911,608 |
| 1872 | 1,369,812 | 500,587 | 984,159 | 2,854,558 |
| 1873 | 1,312,754 | 577,620 | 977,904 | 2,868,278 |
| 1874 | 1,202,144 | 576,557 | 910,712 | 2,689,413 |
| 1875 | 908,046 | 410,990 | 947,545 | 2,366,581 |
| 1876 | 794,578 | 308,649 | 990,009 | 2,093,236 |
| 1877 | 934,797 | 317,843 | 1,061,945 | 2,314,585 |
| 1878 | 1,092,870 | 293,399 | 1,191,092 | 2,577,361 |
| 1879 | 1,273,024 | 358,873 | 1,438,978 | 3,070,875 |
| 1880 | 1,807,651 | 537,558 | 1,950,205 | 4,295,414 |
| 1881 | 1,734,462 | 638,838 | 2,268,264 | 4,641,564 |
| 1882 | ***2,042,138** | **697,906** | 2,438,078 | **5,178,122** |
| 1883 | 1,885,596 | 571,726 | **2,689,650** | 5,146,972 |
| 1884 | 1,586,453 | 458,418 | 2,544,742 | 4,589,613 |

* In the tables **full-faced figures** indicate the maximum product.

## *THE IMPROVED BRÜCKNER CYLINDERS.*

BY R. W. RAYMOND, NEW YORK CITY.

THE Brückner roasting-cylinder is well known as an apparatus which has done good work in the desulphurization, particularly of refractory silver ores, in the western districts of this country. A paper by Mr. J. M. Locke, of Cincinnati, describing the cylinders, as constructed by Messrs. Lane & Bodley, in that city, may be found at p. 295, vol. ii., of the *Transactions* of the Institute; and a paper by Mr. N. H. Cone, vol. iv., p. 226, gives an account of their operation in Colorado. The purpose of the present paper is to present an improved construction, designed by Mr. Brückner. This is clearly shown in the accompanying plate, which scarcely needs explanation. It will be seen at once that this construction involves two cylinders, instead of one. Mr. Brückner thinks that three cylinders might be better yet, as securing an exact mechanical reproduction of the work of the well-known three-hearth *Fortschaufelungsofen*, the most perfect of the reverberatories in which delicate roasting is performed with hand-labor.

### THE APPARATUS.

*Erection of the Cylinders.*—Although the cylinders may be put up at any locality, or added to existing works, it is preferable, if possible, to choose the site on a hill sloping naturally, say about 30° or 33°. Two excavations are made, one 8 to 12 feet higher up than the other; and each is protected by a wall with a batter of about 1 inch to the foot, to prevent slides of stone and earth. Each cylinder being 20 feet long and 7 feet in diameter, the total excavation should be 60 to 70 feet along the hill, and 15 to 25 feet wide. On each level a building is erected 35 feet long by 20 feet wide and 12 feet high, with the roof containing a ventilator against the hill. When both buildings are on the same level, there should preferably be a solid frame-work of very heavy timber, to carry the four rollers which bear the upper cylinder. The four rollers carrying the lower cylinder should preferably rest on two very heavy pieces of timber, strongly braced together and laid to their top in a foundation made of stone or brick and cement. Foundations are necessary only under each two opposite rollers, but they must be made carefully,

because some little vibration in the movement of the cylinder cannot be avoided.

*The Lining of the Cylinders.*—Many persons believe that it is necessary to have fire-brick made in circular segments of the diameter of the cylinder. This is a good thing, but unnecessarily expensive. Common bricks, laid flat (not on edge) into good fire-clay mortar, will wear for many years without loosening or abrasion, being protected in most cases by a crust of sintered ore which forms on them. To make the mortar, Mr. Brückner uses two parts of ground fire-brick to one part of ground fire-clay, and a small percentage of salt which aids in cementing the brick to the outer shell. No bracing is required; the lining forms a ring about three inches in thickness, which is, of course, a double arch, and braces itself. The three inches of the thickness of the lining furnishes a sufficiently bad conductor of heat, so that when it is red-hot inside the outside shell is hardly ever hotter than 100° C. The expansion is about the same in the inside brick and the outside iron. This thickness of lining is recommended for the iron stack also.

It is a common mistake to think that iron is rapidly destroyed in the presence of sulphur or sulphurous acid. Everybody who has ever made sulphide of iron for the manufacture of sulphuretted hydrogen knows that he has to heat the iron first to *white* heat before he adds the sulphur, otherwise it would not smelt and run out at all. At lower heat the action is very slight, and slow. An iron stack, even without lining, lasts for many years, *if always in operation.* Of course, if the furnace is idle half the time it corrodes by exposure to air and moisture. It is therefore best, if a substantial and cheap stack is required, to make it 3 or 4 feet in diameter of No. 10 iron, and line it with brick in the manner explained above. A height of 60 feet is considered sufficient; a damper ought to be provided at the bottom-flue leading to the stack, for the purpose of regulating draft.

*Fire-places.*—For the purpose of lightness, and convenience of easy erection, Mr. Brückner makes his fire-box of iron lined with 5 inches of fire-brick. For wood, the grate is 5½ feet long by 30 inches wide; for coal, square, with about the same area. These fire-boxes can be set on small rollers, so as to be easily removed when the cylinder is to be cleaned from incrustations.

To regulate the heat, it is well to have a second fire-box on one side of the flue connecting the two cylinders; and a third may be

useful to roast the raw flue-dust before it enters the condensing chambers.

*Dust- and Condensing-Chambers.*—The precious metals are volatilized in roasting, especially in the presence of chlorine, arsenic, antimony, lead and zinc. This is well known since the earliest days of metallurgy, and elaborate experiments have been made to determine the conditions of volatilization by the ablest metallurgists, such as Malaguti, Durocher, Plattner of Freiberg, and, lately, by Messrs. Aaron, Falkenau and Reese, Küstel, Riotte, and Stetefeldt.*

Mr. A. Raht, at present superintendent of works at Wickes, Montana, says that, according to his experience, the German process (*Fortschaufelung* and *Sinterung*) is not adapted to the ores of that locality when they contain much zinc, arsenic, etc., and that it is preferable to roast such ores at low heat, and not to sinter to a slag, which would cause much loss. Everybody advises low temperature. It is also generally admitted that the volatilization in Stetefeldt's instantaneous roasting process is much less than in the reverberatory.

The dust- and condensing-chambers are evidently of great importance. The common construction is that of flues, sometimes (in Wales) several miles long, extending from the furnace to a chimney on the top of a hill. Sprays of water, and forcing or sucking the draft through water, have been tried with doubtful success. The best results have been obtained in flues by dividing the draft with screens (Wilson & French's lead-fume condenser). Experiments in condensing fumes by forcing the contents of the flues through water containing screens have also been made at Lautenthal, Germany. Filtering through towers filled with wet coke is employed to condense the Cl and HCl gases in the roasting of Spanish pyrites in England and at Oker in Germany.

A very good condenser has been constructed by Frendenberg, of Ems, Germany, which has been successfully used at the works in Pueblo, Col., and at other places. It is described in a paper by Professor Egleston, *Transactions*, vol. xi., p. 379.

Mr. Brückner proposes several towers between flue and stack, filled with balls of glass or other suitable material resting on a grate, and kept clean by a spray of water. The contents of the flue are introduced into these towers by means of a Körting steam-blast, and

* See Mr. Stetefeldt's paper, read at this meeting, on the losses of gold in roasting.

filtered through the columns of balls. The different towers are used alternately at short intervals, being so arranged that, when one is shut up by a valve, the contents of the flue are forced through the next, and so on. He regards it as not absolutely necessary to have any valves at all. All the towers may have a common flue, and each its own steam-blast. Blast No. 1 drives the contents of the flue into tower No. 1; and, when that blast is shut off, and blast No. 2 let on, tower No. 2 will be filled, and so on to the end of the towers, when blast No. 1 commences again.

Mr. Brückner has also devised an ingenious arrangement by which a single tower, 20 feet in diameter, suffices to do the work of the series just described. I withhold the details, because he has not yet made application for a patent.

## The Operation.

*Mixing the Charge.*—By far the most important part of the operation is the correct mixing of the charge. In fact, it is almost as essential to success as the right mixing of the charge in smelting. In the latter case, the charge is proportioned to get a good slag; in roasting, the ores are mixed to prevent caking, and to get rid of antimony and arsenic.

Moreover, different charges are prepared, according to the subsequent treatment by smelting, lixiviation, or amalgamation, which the product is to receive. Much attention was given to this matter at the Halsbrücker works at Freiberg, when amalgamation and lixiviation were used, before these processes were more or less superseded by smelting; and the perfection of these celebrated works was due to the large amount of iron-pyrites added to the charge before roasting. Mr. Brückner reports that he was indebted, in Peru, to a very large bank of iron-pyrites, which cropped out close by his works at Morecocha, and with the aid of which he succeeded in chloridizing the very refractory ores of Perrac, consisting of arsenical pyrites and arsenical galena. Smelting was out of the question, because at that high elevation of the Cordilleras (16,000 feet above the sea), fuel is very scarce.

Formerly, it was thought necessary to have a certain percentage of sulphur in the charge for its effect in chloridizing. This, Mr. Brückner thinks, is a mistake. In his judgment, the iron-pyrites is added for volatilizing the arsenic and antimony, and for preventing the formation of arseniates and antimoniates of silver and gold which

resist chlorination. Very little sulphur, or, in its absence, quartz, is sufficient to evolve, when in contact with a very small percentage of salt, the chlorine necessary for chloridizing all the silver contained in the charge, after the arsenic and antimony have been driven off.

Thus, an addition of from 1 to 10 per cent. of iron-pyrites is, in most cases, required for the success of the roasting-process. Another addition has to be made to such ores as are apt to cake, even at the low temperature of the roasting-furnace; it consists of 10 to 25 per cent. of rich tailings. Finally, ores containing lime and alumina have to be mixed with silicious ores, so that silica shall be in excess.

Mr. Brückner recommends also, in many cases, the addition of a small percentage of copper-pyrites, or any other copper-ore, which will be found very beneficial, rendering unnecessary all "doctoring" with bluestone, sulphuric acid, zinc, lime, salt, etc.,—which are not required when the charge is made right *before* roasting. Chloridizing on the cooling-floor is thereby obviated.

*Charging and Discharging.*—When concentrations from the jig are to be roasted for the smelting-process, the cylinders have to be arranged so as to work continuously. As is shown in the drawing, the discharging-end is left open. The ore, wet and coarse, as it comes from the jig, is conveyed from the hopper into the end of the first cylinder. There, it becomes mixed with a layer of hot ore, dries quickly, becomes ignited, travels down the natural incline through the flue into the second cylinder, proceeds down the natural incline formed by the roasting ore, and is discharged into the cooling-conveyer, which has a hollow shaft, containing flowing water. Thence it is conveyed or elevated into the hopper above the smelting-furnace.

Mr. Brückner does not recommend this continuous roasting when the subsequent process is to be lixiviation or amalgamation. In such cases, there is a much better control, if the ore is roasted in charges. For this purpose, the lower end is closed by a flange, and a hopper, large enough to hold a charge of five tons, is used above the little charging hopper-pipe, into which it is caused to charge by means of a screw-conveyer, so as to regulate gradual feed. Suppose the last charge has just been let down, through the opening provided for this purpose in the end-flange, into the lower cylinder. A small amount of red-hot ore is left in the upper cylinder. Now, the new charge is gradually let down, from the hopper, mixed with the hot oxides left from the former charge, becomes hot, and ignites, until the whole charge is put in. After it has been partly desulphurized,

the door at the lower end is opened, and the upper charge drops gradually into the lower cylinder, which has been just discharged into the cooling-conveyer.

After roasting dead, salt or other chemicals are added through the working-door at the back end of the lower cylinder, and the roasting is continued until a sample, taken from the same working door, shows the desired reaction.

It is scarcely necessary to point out that the ore is by this apparatus charged, roasted, discharged, and automatically conveyed to the hopper above the amalgamator or lixiviating tank, thus doing away with handling the ore, and with the very unhealthy labor of the cooling-floor.

The following is Mr. Brückner's estimate of the cost of roasting:

*Daily Expense.*

| | |
|---|---|
| Two roasters, at $4.00, | $8 00 |
| Two cords of wood, at $5.00, | 10 00 |
| Oil, light, and extras, | 2 00 |
| Total, | $20 00 |

Product, 20 to 40 tons of refractory ore roasted in twenty-four hours, the amount being dependent (in inverse proportion) on the proportion of sulphur.

## The Advantages Claimed.

Mr. Brückner claims for his improved apparatus—

1. That for highly sulphurous ores there is a minimum consumption of fuel, the combustion of sulphur in the lower cylinder sufficing to ignite the charge in the upper one.

2. That there is a considerable saving of time, as compared with the single cylinder, which requires one to two hours heating to bring a cold charge to the glowing-point.

3. That a better control is possible, since the working-door at the back-end of the lower cylinder permits the easy removal of incrustations, and also the convenient introduction of salt and other chemicals, *after* the partial removal of sulphur in the upper cylinder. This, again, effects a saving of salt and avoids the formation of a superfluous lot of useless or troublesome soda sulphate.

4. The arrangements for charging and discharging are convenient

and save labor; and particularly the water-cooled conveyer takes the place of a cumbrous cooling-floor.

5. Dust and injurious vapors are almost wholly avoided, or rendered harmless.

6. Some further peculiarities in gearing, etc., permitting high speed (which Mr. Brückner favors) are presented as novel and important improvements. As they are not shown in the drawing, I forbear to mention or discuss them.

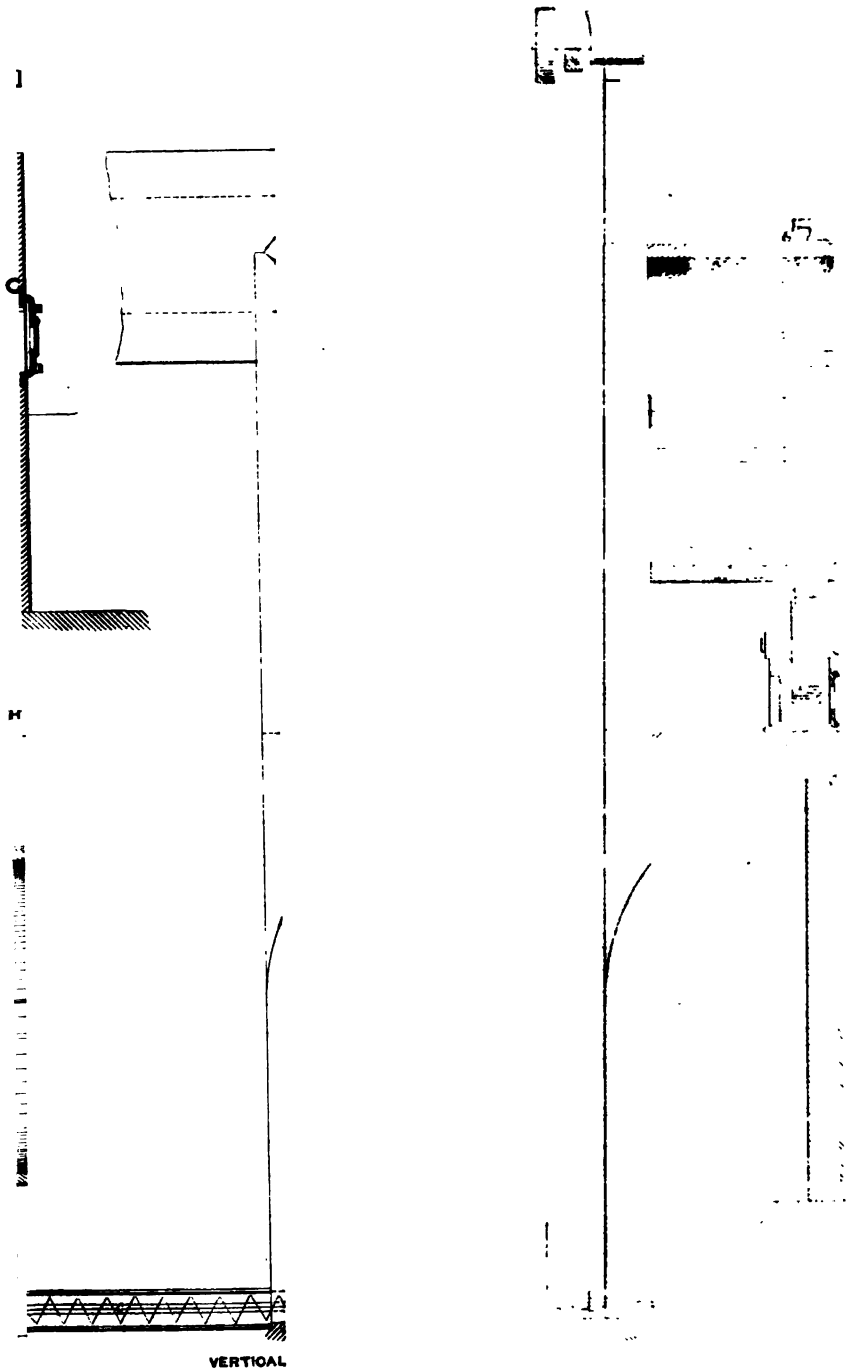
It has been suggested that the cylinders be made conical, to facilitate the travel of the ore, or that, like those of the White and Howell furnaces, they be set at a slight inclination for the same object. But Mr. Brückner has been led by experience to prefer the plain level cylinder, in which the ore forms a natural talus, and the new charges partly overtake and are mixed with the old. This assists roasting and helps to prevent caking. The level cylinder, moreover, can be revolved with less mechanical difficulty and inequality of wear.

## Estimates of Cost.

The following is Mr. Brückner's estimate of cost for a double-cylinder plant, to be erected in Montana.

| | | |
|---|---|---|
| *Iron work.*—2 cylinders 20′ x 7′; 2 fire-boxes, 1 smoke-stack 60′ x 30″, 2 conveyers, 1 hopper and driving-gear, driving-shafts, countershaft, pulleys, pillow-blocks, etc., complete, . . . . . | | $5,850 00 |
| *Freight.*—40 tons from Chicago, at 2 cents per pound, . . . . . | | 1,600 00 |
| *Materials.*—20,000 common brick, at $22.50, . | $450 00 | |
| 16 bbls. fire clay, lime and cement, | 256 00 | |
| | | 706 00 |
| *Labor.*—1 machinist and 2 bricklayers for twenty days, . . . . . | $360 00 | |
| 3 helpers, twenty days, . . . | 180 00 | |
| | | 540 00 |
| *Building.*—60′ x 25′, . . . . . | | 2,300 00 |
| Total, . . . . . | | $10,996 00 |

It will be understood that I claim no originality for this paper. It is simply a statement, based largely upon data obtained from Mr. Brückner, of the main features of his apparatus. His experience and professional standing, as a metallurgist, entitle him to a respectful hearing on the subject; and I hope that the Institute may, before long, have the benefit of information from him, concerning actual practice on a large scale with the furnace here described.


VERTICAL

## *THE SPECIFIC GRAVITY OF LOW-CARBON STEEL.*

BY GEORGE S. MILLER, MINGO JUNCTION, O.

Now that low-carbon steel is manufactured successfully in large quantities by the Bessemer process, and threatens to displace wrought-iron for nearly all purposes, it becomes interesting to find how its specific gravity compares with that of wrought-iron.

The general name "steel" is retained in this paper to designate that metal made by the Bessemer process, which might be more properly called "ingot iron." But the former name seems to be quite firmly established in the iron trade.

This steel offers many inducements to the manufacturer of architectural iron, by reason of its homogeneity, and the large masses in which it may be readily moulded.

The steel from which these determinations have been made, was produced in four-ton heats and cast into ingots of about 3100 lbs. weight, having an average section 14″ by 14″. These ingots were rolled in a blooming-mill to a section about 2½″ by 14″, cut into slabs and rolled in a plate-mill to a plate .065″ to .165″ thick, and about 14″ in width. The specific gravity was obtained from pieces of this plate.

The metal showed by analysis .10 to .12 per cent. carbon, .33 to .45 manganese, .060 to .072 sulphur, .075 to .082 phosphorus, and .010 silicon. The samples were not annealed, but were brought to a bright surface with a file. All figures given are averages of not less than three determinations on separate pieces from the same plate. The variation in the figures from which the averages were made in no case exceeded .015.

| Carbon. | Specific Gravity. | | | |
|---|---|---|---|---|
| Per cent. | .065″ Thick. | .095″ Thick. | .134″ Thick. | .165″ Thick. |
| .10 | 7.809 | 7.857 | 7.862 | 7.866 |
| .11 | 7.807 | 7.850 | 7.862 | 7.864 |
| .12 | 7.800 | 7.847 | 7.866 | 7.862 |
| Average | 7.805 | 7.851 | 7.863 | 7.864 |

Average of whole number 7.844.

Average of .134″ and .165″ thicknesses 7.8635.

With these specific gravities the weight of one cubic foot would be as follows:*

* The weight of a cubic foot of water is taken as 62.321 lbs. at 62° F., at which temperature all determinations were made.

| Carbon. | Weight of one cubic foot. | | | |
|---|---|---|---|---|
| Per cent. | .065″ Thick | .095″ Thick | .134″ Thick | .165″ Thick. |
| .10 | 486.665 lbs. | 489.656 lbs. | 489.968 lbs. | 490.217 lbs. |
| .11 | 486.540 " | 489.220 " | 489.968 " | 490.092 " |
| .12 | 486.103 " | 489.029 " | 490.217 " | 489.968 " |
| Average | 486.415 " | 489.302 " | 490.051 " | 490.092 " |

Average of whole number, 488.965.
Averages of .134″ and .165″ thicknesses, 490.072.

In this connection, the specific gravity of iron rolled from muck bar to similar plate of a thickness of .165″ was found to be 7.680, and the weight per cubic foot 478.625 lbs.

Haswell gives the specific gravity of rolled iron plates as 7.704. One cubic foot of such iron should then weigh 480.121 lbs., or according to his rule (based on 62.5 lbs. as the weight of a cubic foot of water at its greatest density) 481.5 lbs. Of course the varying amount of cinder present in rolled iron accounts for a variation in specific gravity.

The specific gravity of steel plate is given by the same authority as 7.806, which would make one cubic foot weigh 486.478 lbs.; and "soft steel" is put at sp. gr. 7.833, a cubic foot weighing 488.160 lbs.; but further data as to the analysis of the steel, or the dimension of the plates, are not given.

As shown by the above tables, the thinner sections show a lower specific gravity than the thicker. That this will always hold true, the writer would not care to assert.

Determinations of thicker sections were made as follows: thickness, .200″, sp. gr., 7.860; thickness, .224″, sp. gr., 7.866; thickness .300″, sp. gr. 7.865. From these figures, it appears that the maximum specific gravity of a Bessemer steel containing .10 to .12 carbon is attained when the metal is rolled to a thickness of .165″; and that this figure is not varied much for thicker sizes. I am entirely unable to assign a reason for the lower specific gravity of the thinner sections, and feel unwilling to consider it proved till further determinations have been made.

In every determination it was found that the increase of impurities caused a corresponding decrease in the specific gravity, and that any increase in the percentage of carbon caused a corresponding decrease in the specific gravity. To this last statement there is an apparent exception in the figure for .12 carbon, .134″ thickness. This higher gravity, however, is due to a lower percentage of manganese than that in the other samples of the same carbon-tenor.

From these figures I would therefore deduce the specific gravity of a Bessemer steel with .10 to .12 per cent. carbon, and .35 to .45 manganese, as 7.8635, and the weight of one cubic foot as 490.072 lbs.

## Discussion.

William Kent, New York City (Communication to the Secretary): About five years ago I had occasion to make some determinations of specific gravity of open-hearth steel boiler-plate of analysis approximately as follows: carbon 0.14, phosphorus 0.03, silicon 0.02, sulphur 0.02, manganese 0.30. Five pieces of plate ¼-inch thick gave these results: sp. gr., 7.9328; 7.9320; 7.9318; 7.9356; 7.9275—average, 7.9319; maximum variation, 0.0081. My note-book contains the remark made at the time, in explanation of these unusually high figures: "This steel is probably purer than any steel of which the specific gravity has ever been published."

The observation made by Mr. Miller, that increase of impurity causes decrease in specific gravity, is, I believe, correct beyond question. His other observation, that the thinner plates show a lower specific gravity than the thicker, can be explained by the fact that errors in determination of specific gravity are more likely to occur in thin plates on account of their presenting a greater surface in proportion to their weight, than thicker plates; the surface retaining air to some extent, which prevents the water from thoroughly wetting the piece while making the weighing in water. The pieces I used were first planed to remove all possible scale indentations, then filed smooth, then cleaned in dilute sulphuric acid, and then boiled in distilled water, to remove all traces of air from the surface. In my determination of the specific gravity of the copper-tin and copper-zinc alloys (*Reports of U. S. Iron and Steel Testing Board*, vol. i.) I found these precautions necessary to remove the air from the pieces. In some cases, in order to obtain duplicate results, the pieces were washed in alcohol, then in distilled water, and then placed under an air-pump and the air exhausted for a long time before weighing in water.

The figures of specific gravity thus obtained by careful experiment on bright, smooth pieces of steel are, however, too high for use in determining the weights of rolled plates for commercial purposes. The actual average thickness of these plates is always a little less than is shown by the calipers, on account of the oxide of iron on

the surface, and because the surface is not perfectly smooth and regular. A number of experiments on commercial plates, and comparison of other authorities, led me to adopt the figure 7.854 as the average specific gravity of open-hearth boiler-plate steel of the best quality, and to use it in a table of weights of plates, which I constructed for use in the steel-works. This figure is easily remembered as being the same figure with change of position of the decimal point (.7854) which expresses the relation of the area of a circle to that of its circumscribed square, or one-fourth the ratio of the circumference to the diameter. Taking the weight of a cubic foot of water at 62° F. as 62.36 pounds (average of several authorities), this figure gives 489.775 pounds as the weight of a cubic foot of steel, or the even figure, 490 pounds, may be taken as a convenient figure, and accurate within the limits of the error of observation.

A common method of approximating the weight of iron-plates, is to consider them to weigh 40 pounds per square foot one inch thick. Taking this weight and adding 2 per cent. gives almost exactly the weight of steel boiler-plate given above ($40 \times 12 \times 1.02 = 489.6$ pounds per cubic foot).

# PROCEEDINGS

OF THE

# ANNUAL (XLIVth) MEETING IN PITTSBURGH.

*FEBRUARY, 1886.*

## *PROCEEDINGS OF THE FORTY-FOURTH (ANNUAL) MEETING, PITTSBURGH, FEBRUARY*, 1886.

### LOCAL COMMITTEE.

Wm. R. Jones, *Chairman;* Jos. D. Weeks, *Secretary* and *Treasurer;* Wm. Metcalf, B. F. Jones, John H. Ricketson, O. P. Scaife, Wm. Thaw, Jr., Alfred E. Hunt, W. L. Scaife.

*Headquarters Committee.*—Alfred E. Hunt, *Chairman;* T. B. Kerr, *Secretary;* James Hemphill, Harvey Chess, S. A. Ford, H. C. Singer, Geo. H. Clapp, C. Edward Stafford, Geo. E. Thackray, James M. Camp, Will White, Jr., James Todd, James G. Dagron. *Headquarters* were at the Monongahela House.

Sessions were held in the chapel of the First Presbyterian Church, corner of Wood street and Sixth avenue.

The Engineers' Society of Western Pennsylvania kindly tendered to the members of the Institute the use of their library and reading room, Germania Bank building, corner Wood and Diamond streets.

### First Session.

The opening session was held on Tuesday evening, February 16th. The Institute was welcomed to Pittsburgh by Mr. John M. Chalfant; and President Bayles, after acknowledging this welcome and alluding briefly to the attractions of Pittsburgh, and the great changes and improvements which had taken place since the last meeting of the Institute in that city, in May, 1879, proceeded to deliver the Presidential address, the subject being Professional Ethics.*

A paper on Pittsburgh and vicinity was read by W. P. Shinn, Pittsburgh, Pa. This was followed by an address on Natural Gas, from William Metcalf, Pittsburgh, Pa.

After a humorous analysis and burlesque of the scientific theories concerning the origin and quantity of the natural gas-supply, Mr. Metcalf continued as follows:

Having settled the quantity, the next question that naturally arises is, What use do we make of it? I can say that we use it everywhere. If you go into our mills you find it used for puddling. The puddler no longer has to wrestle with great piles of coal, and

---

* Printed on a succeeding page as a separate paper.

rattle grate-bars, shovel out ashes and do the hard work of his business, but, as one of our largest ironworkers says very truly, he now does his puddling with kid gloves on. He has only little valves to turn. You will also find it in our heating and our melting furnaces. You will find everywhere that the hard and dirty labor, the breathing of the fumes of coal-smoke, and ashes, are all done away with, and you will find all the men who are operating in our mills correspondingly happy in the utilization of this natural gas. Go into the boiler-house; it is no longer the dirtiest and smokiest and hottest place around; the men are no longer the most difficult and troublesome to handle; but you will see the walls whitewashed, the boilers painted, the floors swept up, and the fireman sitting there, probably in a comfortable arm-chair, watching the gas- and water-gauges, one man where twenty were required before. You will also find it used for domestic purposes in very many, if not all, of our houses, and all the people correspondingly delighted. The ladies rejoice that they have no coal to be carried upstairs or lugged around the house, no dropping of heavy lumps on the carpets, and no scattering of ashes around the house, no dirt and no trouble; and you might think that you had come to the elysium of combustion.

But is it an unmixed blessing? It is true that in the house the grate which used to be all black and grimy is whitewashed and painted, and filled up with beautiful brickbats, which are also whitewashed. Then there is the beautiful gas fire, and it seems to be whitewashed; and the whole thing is very ghastly-looking, indeed. You would naturally think there certainly could be nothing but a blessing here. Let me describe briefly the way in which the gas is introduced into the fireplace. The grate is cleaned out, the inevitable plumber comes and brings a large cast-iron plate, which is hollow, anywhere from 12 to 18 inches long, and 12 inches wide, perhaps, and 1 inch deep, with an arrangement to fasten a pipe on the under side, and a whole lot of little holes at the top and side. That is called a "combustion-chamber," or mixing-chamber. To that they fasten a pipe with a little cap, which works on the principle of an injector, called an "air-mixer." Below that, they fasten on the gas-pipe; and then they are ready to turn on the gas and burn it, you will say. Not by a good deal. They first fill the grate with brickbats, or old crucible, or chunks of slag, or anything of that kind, and then they turn on this gas, which is about one-half the weight of air, under a pretty lively pressure—they say only 4

ounces, but you will consider what 4 ounces more than the atmospheric pressure means when the gas is only half the weight. They say that this is a great deal "drier" fire than a coal fire. Why it is drier I do not know, because all of the gas I have ever seen is full of salt water; but they say it is. I venture to say that in every house in this city where that abominable contrivance is used, inside of six months the physician will recognize a distinct and very serious set of diseases due to natural gas; and if I were going to make a prediction, it would be vertigo, fulness of head, tendency to apoplexy, nausea, sore throat, and dried-up lungs. That is the unmixed blessing of using it as a domestic comfort in the way in which it is now applied. I have tried it in my office for a few weeks; and I promise if any of you should come here next winter, if I cannot find some other way to burn it in the office, you will find the coal-bucket, the poker, and the tongs there.

But in the mills it is surely, one would think, an unmixed blessing. I ought to have said, by the way, that in the houses it costs a good deal more than coal; but surely in the mills it costs much less than coal, surely it is much cheaper, surely it has done away with a great deal of labor, surely it has reduced the wear and tear in every way. Certainly there it must be an unmixed blessing. Well, that is a very great mistake. There is not a manufacturer in Pittsburgh to-day who has been using natural gas in his mills for six months who is thinking what coal ever cost him, or what the labor of handling it cost him, or what the labor saved by doing away with the using of coal has amounted to. He is altogether engaged in figuring up just how many thousand dollars a year he is paying to that abominable gas company, and trying to devise some way to reduce it. We have got altogether away from the economical advantages. Then, when you consider the number of firemen, laborers, and gasmakers, and the thousands of coal-diggers, who have been thrown out of their usual avocations by the introduction of this natural gas—be it said to their credit, without a murmur; they have had the intelligence and the character, which they all possess, of first-rate American citizens, to accept the inevitable and make the best of it without a complaint—if you go among them you will hardly find that they will say the introduction of natural gas is an unmixed blessing.

Now, what of the future? We heard a little of one side of it to-night—the side which looks brightest for Pittsburgh; let us look at another side. In the first place, as I have said, our manufacturers

have already forgotten what coal used to cost them, and are figuring now to get gas cheaper. In the second place, all the rest of the world still believes that there are some very great economical advantages in Pittsburgh in the use of natural gas; and you gentlemen who are visiting us have come here to study what those economical advantages are, in order that you may go back to your homes determined that Pittsburgh shall not absorb all of the manufacturing industries of the world—determined that you will study out the best method, and the most economical, of reducing slack, anthracite-dust, and everything else to gas, and get a cheap fuel which shall enable you to at least live against the competition of Pittsburgh; and, if you will bear in mind what I have told you about the forgetfulness of the Pittsburgh manufacturer already, you will not find the path quite so hard as you thought it might be. That will be your earnest study. The best brains—the best engineering brains at least—of all the country will be devoted to studying the most economical mode of using and utilizing the solid fuel outside of the district where the natural gas is easily obtained.

It might be supposed that while that was going on the engineers in Pittsburgh would, of course, follow up your progress and your studies and keep themselves posted and well informed, but we will not do anything of the kind. Whenever we pick up *The Iron Age* or the *Engineering and Mining Journal* and see a description of your economical and beautiful gas-furnaces, and the figures as to how cheaply you can make gas, and what quantities of steel and iron you can puddle, and so on, to a ton of coal, we will pitch it all aside. We have no interest in that. We have natural gas—that will do for us. We don't want to be bothered about any other fuel.

But if we should come to the end of our equation of quantity, and should happen to find that infinity was not exactly the correct answer, what would be the result? We would have not a manufacturer in the town who would know the proper cost of solid fuel; not an engineer who would know how to build a good gas-plant; not a puddler who would know how to handle a furnace fired with coal; not a heater who would know how to make a heat of iron or steel with solid fuel; not a glass-maker who would know how to make glass without natural gas, and not a fireman who would know how to raise steam with coal. Then, when the manufacturer began to find out, or to suppose, that his coal was going to cost him a great deal more than his gas did, he would say, "Well, I have got to have all this work done a great deal cheaper;" and when the puddler, and the heater,

and the fireman, and the gas-maker found that they had to go back and double up the amount of labor they had to do before, and wrestle with this dirt and ashes and so on, they would say, "We are not going to do this double work for these wages, and we want our wages increased." The result would be an almost universal hubbub in this community; there is going to be a pretty lively time if natural gas gives out, if you can possess your souls in patience until that day.

You might say, perhaps, it will be a very bad time. It will be bad in one sense: it will be noisy, probably; but there is a good, old, solid, substantial element in this town, which has covered it all over not only with its industries, its warehouses, its factories, mills, and all that, as well as such buildings as this in which we are meeting, but which is fully imbued with the principle laid down in our government by our old Puritan fathers, that the only safety to the community is for every man to obey the law; and there is very little danger, if we are left to ourselves, that we shall have any more serious trouble when that time comes than a very great hubbub. It will be one side against the other; and it will go on with a good deal of noise, but without calling in any outside assistance and without the smashing of any furniture, until one side or the other will find that the other side is in dead earnest, when the side which is not quite so much in earnest will back down, and we shall shake hands and go ahead again.

But you have been told in Mr. Shinn's paper we are going to double this town in fourteen years. I have even been told that we are going to treble it and quadruple it, and that in the next ten or fifteen years we will have 500,000 population in the city of Pittsburgh. Now if that comes to pass, and if the people who come in here are not just exactly the same kind of people as we are, and if they do not understand just how to indulge in these little family quarrels without hurting anybody, as we do—if we get 500,000 people here who are entirely unconversant with our way of doing things, then there may be very serious results; and in that case I can only say to any of you gentlemen who may have come here (although I do not know that any of you have) with any idea of looking around to see if this is a good place to locate or not, If you expect to live a long time and enjoy an old age, with peace and quietness, don't come!

After the close of Mr. Metcalf's remarks, a Biographical Notice of Oswald J. Heinrich was read by Dr. R. W. Raymond, New York City.

The President appointed as Scrutineers, to count the ballots for officers, Messrs. J. C. F. Randolph, John B. Porter, and F. Lynwood Garrison.

### Second Session.

The second session was held on Wednesday evening, February 17th, when the following papers were read:

The Geology of the Pittsburgh Coal Region, by J. P. Lesley, State Geologist of Pennsylvania, Philadelphia, Pa.

Peculiar Phenomena in the Heating of Open-Hearth and Bessemer Steel, by William Garrett, Pittsburgh, Pa.

Notes on the Constitution of Cast-Iron, by C. B. Dudley and F. N. Pease, Altoona, Pa.

The Microscopic Structure of Car-Wheel Iron, by F. Lynwood Garrison, Philadelphia, Pa.

### Third Session.

At the third session, held on Thursday morning, the following papers were read:

The Mining Compass and Trigonometer, by Erich G. Gaertner, New York City.

The Clapp-Griffiths Converter—Later Practice and Commercial Results, by J. P. Witherow, Pittsburgh, Pa.

Recent Failures of Steel Boiler-Plates, by William Kent, New York City (read, in the absence of the author, by the Secretary).

Soft Steel for Boiler-Plates, by Alfred E. Hunt, Pittsburgh, Pa.

The paper of Mr. Witherow elicited a lively discussion, pending which the time for adjournment arrived.

### Fourth Session.

The fourth session was held on Thursday afternoon, when, after the conclusion of the pending discussion, the following papers were read:

The Iron-Ore Deposits of Southern Utah, by W. P. Blake, New Haven, Conn. (read, in the absence of the author, by the Secretary).

The Cornwall Iron-Ore Mines, Lebanon, Pa., by E. V. d'Invilliers, Philadelphia, Pa. (In connection with this paper, a topographical model of the Cornwall region, constructed by A. E. Lehman, Philadelphia, Pa., was exhibited.)

A New Method of Submarine Tunneling, by R. P. Rothwell, New York City.

The Heine Safety-Boiler, by E. D. Meier, St. Louis, Mo.

## Fifth Session.

The closing session was held on Friday evening, February 19th, when the following papers were read:

Mitis-Castings of Wrought Iron or Steel, by Petter Ostberg, Stockholm, Sweden.

The Product of Iron-Ore at Hibernia Mines, N. J., by J. Wesley Pullman, Philadelphia, Pa.

The following papers were read by title:

The Sampling of Cast-Iron Borings, by Porter W. Shimer, Easton, Pa.

Operation of Warwick Furnace, Pa., from August 27th, 1880, to September 1st, 1885, by John Birkinbine, Philadelphia, Pa.

The Process Used at the Comstock for Refining Coppery Bullion from the Amalgamation of Tailings, by A. D. Hodges, Jr., Boston, Mass.

The Use of Gasoline Gas in a Chemical Laboratory, by Prof. Charles E. Wait, Rolla, Mo.

A Cupel-Machine, by Prof. Charles E. Wait, Rolla, Mo.

A Chilled Furnace-Hearth, by James Gayley, Braddock, Pa.

The Classification and Constitution of Pennsylvania Anthracites, by C. A. Ashburner, Philadelphia, Pa.

The Mineral Resources of the Hudson's Bay Territories, by Robert Bell, Ottawa, Canada.

The Nova Scotia Gold Mines, by E. Gilpin, Jr., Halifax, N. S.

Note on a Deposit of Fire-Sand in Clinton County, N. Y., by Alfred F. Brainerd, Birmingham, Ala.

The Manufacture of Fire-Brick at Mt. Savage, Md., by Robert A. Cook, Mt. Savage, Md.

Proposed Apparatus for Determining the Heating-Power of Different Fuels, by William Kent, New York City.

Geology of the Low Moor, Va., Iron-Ores, by Benj. Smith Lyman, Northampton, Mass.

Note on the Determination of Small Quantities of Titanium in Iron or Steel, by Horace L. Wells, New Haven, Conn.

Note on the Reduction of Ferric Solutions by the Use of Amalgamated Zinc and Platinum Foil, by Alfred L. Beebe, New York City.

The following gentlemen, proposed for election as members and associates, and recommended by the Council, were elected:

HONORARY MEMBER.

Dr. John Percy, . . . . . London, England.

MEMBERS.

| | |
|---|---|
| William W. Adams, | Weatherby, Oregon. |
| Robert Allison, | Port Carbon, Pa. |
| Carl Amsler, | Pittsburgh, Pa. |
| Charles Archibald, | Cow Bay, C. B., N. S. |
| D. H. Bacon, | Ishpeming, Mich. |
| Charles Bailey, | Pittsburgh, Pa. |
| Frank W. Barnes, | Simmering, Vienna, Austria. |
| Carl W. Bildt, | Worcester, Mass. |
| E. J. Bird, Jr., | Ironton, O. |
| H. W. C. Block, | Belleville, Ill. |
| Amos Bowman, | Ottawa, Canada. |
| Henry A. Boyd, | McKeesport, Pa. |
| Thomas G. Boyle, | Pittsburgh, Pa. |
| George W. Bryan, | Pittsburgh, Pa. |
| Lee Burt, | Detroit, Mich. |
| Alexander M. Byers, | Pittsburgh, Pa. |
| Edw. S. Campbell, Jr., | Candela, Coahuila, Mexico. |
| John F. Carll, | Pleasantville, Pa. |
| R. C. Chambers, | Salt Lake City, Utah. |
| Maurice E. Clark, | Tombstone, Arizona. |
| Emile Collin, | Paris, France. |
| Simon C. Collin, | Braddock, Pa. |
| Alfred H. Cowles, | Cleveland, O. |
| Eugene H. Cowles, | Cleveland, O. |
| George C. Davies, | Pottstown, Pa. |
| George A. Dean, | Mingo Junction, O. |
| H. F. DeBardeleben, | Birmingham, Ala. |
| George R. Elder, | Johnstown, Pa. |
| Joseph L. Ferrell, | Philadelphia, Pa. |
| George W. G. Ferris, Jr., | Pittsburgh, Pa. |
| Benjamin Fletcher, Jr., | Bridgeport, Conn. |
| James Forsstedt, | Worcester, Mass. |
| Alfred Gaither, | Newport, Ky. |
| P. C. Gallaher, | Leadville, Col. |
| A. Greiner, | Seraing, Belgium. |
| Albert Grothe, | Guanajuato, Mexico. |
| Albert Hartmann, | Belleville, Ill. |
| William H. Hassinger, | Sharpsburg, Pa. |
| Gustavus C. Henning, | New York City. |
| O. Hock, | Isbergnes, P. d. C., France. |
| L. E. Holden, | Salt Lake City, Utah. |
| A. B. Howland, | Titusville, Pa. |
| Ernst C. C. Huhn, | Providence, Cal. |
| Andrew B. Johnston, | Birmingham, Ala. |
| Lewis C. Karrick, | Salt Lake City, Utah. |
| William Kirkland, | Danville, Ill. |
| Per. Larsson, | Iron Mountain, Mich. |
| G. Lavagnino, | Salt Lake City, Utah. |

| | |
|---|---|
| A. Y. Lee, | Pittsburgh, Pa. |
| Thomas R. Lombard, | Yuşcaron, Honduras. |
| Ellis Lovejoy, | Columbus, O. |
| J. H. McRoberts, | Pittsburgh, Pa. |
| G. Macfarlane, | Coalburgh, W. Va. |
| F. P. MacLean, | Washington, D. C. |
| Jacob B. Martin, | Steelton, Pa. |
| David S. Mathias, | Chicago, Ill. |
| Edward D. Meier, | St. Louis, Mo. |
| Hermann V. L. Meigs, | Lebanon, Pa. |
| Wm. N. Merriam, | Madison, Wis. |
| Chas. E. Mitchener, | Stockton, Utah. |
| M. G. Moore, | Johnstown, Pa. |
| Serge Nikitin, | St. Petersburgh, Russia. |
| John M. Norton, | Steubenville, Ohio. |
| Edward Orton, Jr., | Buchtel, Ohio. |
| Petter Östberg, | Stockholm, Sweden. |
| Geo. S. Page, | Braddock, Pa. |
| Chas. Paine, | Pittsburgh, Pa. |
| Rubens P. Patterson, | Birdsboro, Pa. |
| Edward W. Penfield, | So. Chicago, Ill. |
| C. D. Porter, | Salt Lake City, Utah. |
| H. K. Porter, | Pittsburgh, Pa. |
| N. W. Pratt, | 30 Cortland Street, New York. |
| John B. Price, | Mauch Chunk, Pa. |
| Samuel B. Price, Jr., | West Leisenring, Pa. |
| Edw. A. Quintard, | Batopilas, Mexico. |
| August Raht, | Wickes, Montana. |
| Charles H. Read, | Pittsburgh, Pa. |
| Frank Ringeling, | Butte, Montana. |
| Arthur Robinson, | Coalburgh, W. Va. |
| George H. Robinson, | Helena, Montana. |
| Samuel J. Robinson, | Saltsburg, Pa. |
| Walter S. Russell, | Detroit, Mich. |
| George Singer, | Pittsburgh, Pa. |
| Frederick Sloss, | Birmingham, Ala. |
| Charles L. Springer, | Oliphant Furnace, Pa. |
| John K. Taggart, | Leisenring, Pa. |
| Frank G. Tallman, | Beaver Falls, Pa. |
| Selwyn Taylor, | Pittsburgh, Pa. |
| R. H. Terhune, | Salt Lake City, Utah. |
| F. H. Treat, | Joliet, Ill. |
| James W. Tyson, | Baltimore, Md. |
| Edward A. Uehling, | Bethlehem, Pa. |
| William J. B. Walker, | Mansfield Valley, Pa. |
| Wataru Watanabe, | Tokio, Japan. |
| George Westinghouse, Jr., | Pittsburgh, Pa. |
| James B. White, | Pittsburgh, Pa. |
| John F. Wilcox, | Pittsburgh, Pa. |

| | |
|---|---|
| Gardner F Williams, | Oakland, Cal. |
| Henry S. Williams, | Ithaca, N. Y. |
| E. A. Wiltsie, | Braddock, Pa. |

ASSOCIATES.

| | |
|---|---|
| Edward O'Connor Acker, | Washington, D.C. |
| Thomas W. Bakewell, | Pittsburgh, Pa. |
| Joseph R. Bien, | New York City. |
| C. G. Blake, | Cincinnati, O. |
| W. A. Connell, | Portsmouth, O. |
| M. C. Davis, | Pittsburgh, Pa. |
| Clarence H. Dimock, | Windsor, Nova Scotia. |
| Richard M. Edwards, | New York City. |
| Phil. Van Frank, | Hopewell Furnace, Mo. |
| Thomas A. Gillespie, | Pittsburgh, Pa. |
| Simon H. Holmes, | Halifax, Nova Scotia. |
| Laclede I. Howard, | St. Louis, Mo. |
| Epenetus Howe, | New York City. |
| John H. Janeway, Jr., | Governor's Island, New York City. |
| Edward M. McIlvain, | Reading, Pa. |
| W. G. Mather, | Cleveland, O. |
| Arthur Neustaedter, | St. Louis, Mo. |
| Alexander Niedringhaus, | St. Louis, Mo. |
| John R. D. Owen, | Rolla, Mo. |
| Duff Porter, | Chicago, Ill. |
| Henry H. Porter, Jr., | New York City. |
| William H. Rea, | Pittsburgh, Pa. |
| Conrad Reinecke, | Belleville, Ill. |
| Charles C. Scaife, | Pittsburgh, Pa. |
| S. L. Schoonmaker, | Pittsburgh, Pa. |
| Robert J. Steen, | Philadelphia, Pa. |
| Edward A. Swain, | New York City. |
| J. Viennot, | Philadelphia, Pa. |

The status of the following Associates was changed to membership:

| | |
|---|---|
| Walter C. Hadley, | S. Albert Reed, |
| Leon Marié, | C. Snelling Robinson, |
| R. van A. Norris, | Theodore W. Robinson, |
| C. F. Pearis, | William Burnham, |
| W. F. Pinkham, | Neil Robinson. |

The Secretary read the following Report of the Council:

## Report of the Council.

In accordance with the rules, the Council makes the following report to the Institute:

The financial statement of the Secretary and Treasurer, duly audited, shows receipts for the year from all sources, of $16,864.62, and expenditures of $12,884.54, leaving a surplus of $3980.08. In

addition to this, the Treasurer holds U. S. bonds belonging to the Institute as follows: 4 per cent. bonds, par value, $900; 4½ per cent. bonds, par value, $440; total, $5300. The present value is about $6500.

Since the balance from the last statement was $1667.89, the actual receipts of the year were $2312.19 greater than the expenditures.

The detailed statement is as follows:

*Statement of the Secretary and Treasurer, of Receipts and Disbursements, from February 1st, 1885, to January 31st, 1886.*

| | | | |
|---|---|---|---|
| Balance from last statement, | | $1,667 89 | |
| Received for dues from members and associates, | | 12,762 24 | |
| " " life-memberships, | | 400 00 | |
| " " sale of publications, | | 785 33 | |
| " " binding TRANSACTIONS, | | 542 33 | |
| " " authors' pamphlets, | | 289 70 | |
| " " engraving and electrotypes, | | 114 90 | |
| " " portraits of Holley, | | 2 00 | |
| " " exchange and mailing volumes, | | 63 | |
| " " interest on United States bonds, | $234 00 | | |
| " " " " deposits, | 65 60 | 299 60 | $16,864 62 |
| Paid for printing volume xiii. TRANSACTIONS, | | $2,131 39 | |
| " " binding " " | | 686 75 | |
| " " printing pamphlet editions of papers, | | 1,584 60 | |
| " " " authors' editions of papers, | | 182 00 | |
| " " " list of members, | | 114 50 | |
| " " " mailing list, | | 15 00 | |
| " " " circulars, ballots, etc., | | 68 10 | |
| " " binding miscellaneous volumes, | | 98 15 | |
| " " " exchanges, | | 125 10 | |
| " " engraving and electrotyping, | | 1,107 14 | |
| " " stationery (including postpaid envelopes), | | 353 27 | |
| " " postage, | | 960 88 | |
| " " traveling expenses, mailing books and pamphlets, | | 51 29 | |
| " " janitor's fees, | | 51 00 | |
| " " rent of office, | | 200 00 | |
| " " small expenditures in office (unclassified), | | 81 92 | |
| " " bank-note plate-paper, | | 625 00 | |
| " " purchase of TRANSACTIONS, etc., | | 41 50 | |
| " " storage of TRANSACTIONS (adv. for 1886), | | 147 20 | |
| " " insurance of library, | | 5 00 | |
| " " freight, express charges, and duty, | | 40 41 | |
| " " preparing and reading proof of index (vol. xiii.), | | 25 00 | |
| " " telegrams, | | 9 99 | |
| " " salaries of secretary and three assistants, | | 3,980 00 | |
| " " expenses of secretary and assistant at meetings, | | 199 35 | $12,884 54 |
| Balance, | | | $3,980 08 |

Two items of the expenditure in the above statement, viz., the purchase of bank-note plate-paper, and the storage of the *Transactions*, are strictly applicable to the coming year; but, inasmuch as two corresponding items pertaining to this year were included in the expenditures of the last, the sum total of expenditures herewith reported may be considered as about the average cost of carrying on the work of the Institute in the present manner and on its present scale for a year, not including special extra publications. Such publications will doubtless, from time to time, be made.

The Council has now in preparation a handsome geological map of the United States and part of Canada, prepared by Prof. C. H. Hitchcock, and printed in colors, which will be issued to members at an early day, the cost of which will be paid from the surplus now on hand.

The Council takes satisfaction in reporting that the preparation of Vol. XIV. of the *Transactions* promises to be one of the largest and most valuable of the series, and is now even further advanced than that of Vol. XIII. was at the last annual meeting. All the papers, except those presented at this meeting, have been printed, distributed, and revised for the volume, and nearly all the sheets containing them have passed through the press. It is hoped that by the continued coöperation of the authors of papers in the prompt preparation of manuscript and revision of proofs, the early appearance of Vol. XIV. may be secured.

Three meetings have been held during the year. The annual (XLIst) meeting in New York, a May meeting in Chattanooga, Tenn., and a September meeting in Halifax, N. S.

The printed proceedings of these meetings, already distributed to members, sufficiently indicate their instructive and delightful character, although no printed words can adequately express the charm which from the beginning has attended these reunions, and which is still continued unimpaired.

Changes in membership since the last annual report have been as follows:

One honorary member, 63 members, and 13 associates have been elected and have accepted their elections; 21 members and 9 associates have resigned; and 24 members and 7 associates have been dropped from the rolls for non-payment of dues.

The list of deaths comprises 11 members: C. M. Atkins, Jr., F. D. Browning, Wm. Clark, W. S. Clayton, Wm. B. Crocker, Edward

S. Davies, Harvey Fisher, O. J. Heinrich, W. C. Kerr, Walter Tefft, and W. J. Wood.

Of these Mr. Clark's death occurred in 1884, but was not reported.

These changes are tabulated as follows:

| | H. M. | F. M. | M. | A. | | |
|---|---|---|---|---|---|---|
| At date of last report | 5 | 48 | 1207 | 154 | 1414 | ..... |
| GAINS: By election | 1 | ..... | 63 | 13 | 77 | ..... |
| By change of status | ..... | ..... | 2 | ..... | 2 | ..... |
| LOSSES: By resignation | ..... | ..... | 21 | 9 | ..... | 30 |
| By dropping from roll | ..... | ..... | 24 | 7 | ..... | 31 |
| By change of status | ..... | ..... | ..... | 2 | ..... | 2 |
| By deaths reported | ..... | ..... | 11 | ..... | ..... | 11 |
| Total gains | ..... | ..... | ..... | ..... | 79 | ..... |
| Total losses | ..... | ..... | ..... | ..... | ..... | 74 |
| Present membership | 6 | 48 | 1216 | 149 | 1419 | ..... |

The strict revision of the list of members and associates explained in the last annual report has been continued during the present year. Although, therefore, the total list of membership is not substantially larger than that reported a year ago, it is believed to represent a more compact body of sincerely interested persons. Names have been dropped for the following causes only: failure to pay dues for two years and to respond to the letters of the Secretary concerning arrears of dues; repeated failure to make good promises given with regard to payment of arrears; return of communications from the post office and inability of the Secretary to ascertain address. But no name has been dropped, even for any of these causes, when there was reason to believe that the non-payment of dues was an unintentional oversight which would be corrected; and in all cases where names have been dropped the Council is ready to authorize their restoration upon satisfactory explanations and payment of arrears.

The number of members in arrears for the present year, many of whom will doubtless pay soon, is 99, but the Council considers this, in view of the numerous and scattered membership of the Institute, the frequent temporary absence of the members from their homes and even from the country, and the inconvenience of making small remittances, particularly from the mining districts, where many of the delinquent members are stationed, a not discreditable proportion.

The Scrutineers appointed at the first session of the meeting reported the following officers elected:

*PRESIDENT.*

| | |
|---|---|
| ROBERT H. RICHARDS, . . . . . | Boston, Mass. |

*VICE-PRESIDENTS.*

(To serve for two years.)

| | |
|---|---|
| W. B. COGWELL, . . . . . | Syracuse, N. Y. |
| JAMES F. LEWIS, . . . . . | New York City. |
| J. D. WEEKS, . . . . . | Pittsburgh, Pa. |

*MANAGERS.*

(To serve for three years.)

| | |
|---|---|
| H. M. HOWE, . . . . . | Boston, Mass. |
| J. E. JOHNSON, . . . . . | Longdale, Va. |
| W. G. NEILSON, . . . . . | Philadelphia, Pa. |

*TREASURER.*

| | |
|---|---|
| THEODORE D. RAND, . . . . . | Philadelphia, Pa. |

*SECRETARY.*

| | |
|---|---|
| R. W. RAYMOND, . . . . . | New York City. |

On motion of John Birkinbine, Philadelphia, Pa., duly seconded, a resolution was passed unanimously, thanking the Local Committee for its zealous and skilful services, and instructing the Secretary to express by letters to the various persons, firms, and corporations whose hospitality had been extended to visiting members, the thanks of the Institute.

With a few farewell words from the retiring President, the meeting was adjourned.

## EXCURSIONS.

The following account of the excursions of the meeting is taken from the *Iron Age*, of New York:

WEDNESDAY, February 17th.—At 9 o'clock A.M. a special train, furnished by the courtesy of the Pennsylvania Railroad Company, left the West Pennsylvania depot in Allegheny, for a trip over the West Pennsylvania Railroad and the Allegheny Valley Railroad. The day was devoted chiefly to the inspection of natural gas and its uses in various processes of manufacture. Eight passenger coaches were filled with the visiting and local members; and when the train returned to the Union station, in Pittsburgh, at 5 o'clock in the evening, only one minute behind the advertised schedule, the excursionists were loud in their praises of the beauty of the day and the enjoyability of the trip. The first stop was made at the Pittsburgh Plate Glass Works, at Creighton. At this place the members were convinced of what few of them had even heard rumored, viz., that

plate glass equal to the best imported French glass was being made in the United States. At these works there are two furnaces in operation, one with 12 pots and the other with 16, and a third with 20 pots is building. The present capacity of the works is 16,000 square feet per week. The visitors had an opportunity to inspect the entire operation of making plate glass, from the casting, rolling, grinding, smoothing and polishing to the cutting and packing. Each visitor was presented with a beautiful specimen of the product of the works, showing as fine polish and as clean color as the best imported.

After running 2 miles the train stopped at Tarentum, where some 200 of the excursionists took carriages to visit Station No. 5 of the Philadelphia (Westinghouse) Gas Company, 1½ miles distant. At this place the gas was allowed to blow off to show the visitors the pressure of the well.

On the return the train was run to Freeport, where it crossed the Allegheny River to its left or Pittsburgh bank, at which point the Allegheny Valley Road was taken, the return trip to the city being made over this road. A most elegant lunch was prepared and served under the auspices of Mr. Schlosser, of the Duquesne Club. The center-piece on the table was a 38-pound salmon ornamented with the Institute coat-of-arms. Freeport was reached, the river crossed and the train on its way to the city before the lunch had been fully served and the vote of thanks tendered to Mr. Schlosser. The Crescent Steel Works, of Miller, Metcalf & Parkin, at Lawrenceville, were reached after 2 o'clock, and half an hour was spent in inspecting this most complete crucible-steel works. The ladies were especially interested in the very fine rods for dental instruments and the exceedingly fine steel wire.

At Thirty-sixth street a stop was made in order that the natural gas might be turned into the blow-off pipes of the Philadelphia Gas Company. The gas was turned into the four 8-inch stand-pipes, which are 200 feet high, and the roaring of the escaping gas and brilliancy of their united flame, when lighted, evoked constant expressions of astonishment.

The largest steel hammer in the United States was seen at Park, Bro. & Co.'s steel works, where a stop of a few minutes was made, after which the excursionists visited and inspected the O'Hara Glass Works, being chaperoned by Mr. James B. Lyons, who has been so long connected with the glass industry of this city. One of the most interesting features of the visit to the works, to the engi-

neers present, was the arrangement for supplying benzine to the furnace-fires in case of short supply of gas, or an accidental or intentional cutting-off of the supply. The ladies were especially interested in the beautiful samples of colored glass and imitation of diced cut glass here shown. The last visit was made to the works of the Pittsburgh Steel Casting Company, where Mr. William Hainsworth's methods of rabbling the steel in a Bessemer converter after recarbonization, and his soaking-pits, which in some of their features antedate Gjer's, were inspected.

FRIDAY, February 19th.—The special train bearing the excursionists left the Pittsburgh and Lake Erie station at 10 A.M. The number was much larger than on Wednesday, some 300 filling the coaches provided by the Pennsylvania Railroad Company.

The first stop was at the Tenth street depot, to visit the glass works of Duncan & Son, and the rod-mill of Oliver Brothers & Phillips. At the Duncan Glass Works the various processes of manufacturing colored glassware were witnessed and explained.

The next place visited was the Clapp-Griffiths works of Oliver Brothers & Phillips. As this plant and its operations have been so thoroughly described, it need only be said here that the visitors were delighted and many of them were interested and convinced as to the merits of the process.

Jones & Laughlin's mill was next visited, chiefly to see the application of natural gas in its various departments.

Lunch was served on the train *en route* to the Edgar Thomson steel works, at Braddock. These works were found so interesting as to delay the party considerably beyond the schedule time; and the train did not reach the Union station at Pittsburgh until after 5 o'clock.

With the exception of a brief storm on Friday, the weather was exceptionally fine throughout the meeting; and Pittsburgh, under fair skies, and freed from the larger part of its ancient overhanging and all-pervading atmosphere of smoke, was a surprise to those who had known it only in gloomier days.

Thursday evening was devoted to a subscription dinner at the Monongahela House.

## MEMBERS AND ASSOCIATES PRESENT.

The following members, associates, and guests registered their names at the headquarters of the Local Committee:

A. V. Abbott.
Charles A. Ashburner.
W. L. Austin.
Edward Bailey, Jr.
C. H. Baker.
F. W. Barnes.
P. Barnes.
J. C. Bayles.
C. W. Bildt.
Charles E. Billin.
George H. Billings.
John Birkinbine.
Andrew A. Blair.
F. C. Blake.
A. W. Bliss.
C. R. Boyd.
Jerome L. Boyer.
Walter Lee Brown.
M. C. Bullock.
J. M. Cramp.
J. F. Carll.
John W. Chalfant.
H. M. Chance.
B. W. Cheever.
H. B. Chess.
A. H. Childs.
F. W. Christie.
Charles E. Clapp.
George Clapp.
Ellis Clark, Jr.
F. G. Coggin.
W. B. Cogswell.
W. A. Connell.
A. B. Cornell.
W. E. C. Coxe.
J. L. Crawford.
R. Crooker, 3d.
B. Crowther.
Gram Curtis.
J. G. Dagron.
R. W. Davenport.
George C. Davies.
A. de Deken.
A. B. de Saulles.
E. V. D'Invilliers.
T. M. Drown.
Herbert DuPuy.
Hunter Eckert.
T. Egleston.
George R. Elder.
F. A. Emmerton.
Charles E. Emery.
F. Firmstone.
C. L. Fitzhugh.
S. A. Ford.
J. Forstedt.
John D. Frossard.
Homer T. Fuller.
E. G. Gaertner.
F. Lynwood Garrison.
J. Gayley.
William R. George.
William Glenn.
H. C. Grittinger.
John H. Harden.
James Hempshire.
C. H. Henderson.
George C. Hewett.
Frank A. Hill.
A. D. Hodges, Jr.
H. O. Hofman.
J. F. Holloway.
L. J. Howard.
H. M. Howe.
A. B. Howland.
W. S. Hungerford.
Alfred E. Hunt.
Robert W. Hunt.
W. A. Ingham.
E. P. Jennings.
W. H. Jennings.
W. R. Jones.
J. Keeley.
Hugh Kennedy.
Thomas B. Kerr.
Frank King.
W. B. Kunhardt.
A. E. Lehman.
Henri Lefebvre.
J. P. Lesley.
N. Lilienberg.
John C. Long.
N. W. Lord.
Ellis Lovejoy.
Jawood Lukens.
M. J. Lunn.
G. Macfarlane.
R. L. Martin.

Jean A. Mathieu.
J. R. Maxwell.
G. W. Maynard.
Archibald Means.
E. D. Meier.
H. V. L. Meigs.
William Metcalf.
George S. Miller.
M. G. Moore.
P. N. Moore.
James Morgan.
Joseph Morgan, Jr.
T. R. Morgan.
J. H. Murdock.
H. McCormick.
S. W. McKeown.
J. K. McLanahan.
J. S. McLennan.
James Neilson.
William G. Neilson.
Edward Nichols.
F. P. Norton.
H. W. Oliver.
Edward Orton.
Edward Orton, Jr.
Petter Ostberg.
S. P. Pardee.
C. O. Parsons.
W. B. Parsons, Jr.
F. V. Pease.
Edmund C. Pechin.
Leonard Peckitt.
W. I. Pierce.
W. P. Pinkham.
John B. Porter.
William B. Potter.
W. H. Powell.
J. W. Pullman.
J. C. F. Randolph.
R. W. Raymond.
Charles H. Read.
S. A. Reed.
Jacob Reese.
R. B. Reid.
C. Reinecke.
R. H. Richards.
J. H. Ricketson.
William B. Ridgely.
Percival Roberts.
Percival Roberts, Jr.
J. S. Robeson.
D. S. Robinson.
Neil Robinson.
R. P. Rothwell.
O. P. Scaife.
W. L. Scaife.
F. Z. Schellenberg.
S. L. Schoonmaker.
George Schuman.
H. Schulze-Berge.
Frank Scott.
Minor Scovel.
S. T. Scheaffer.
William P. Shinn.
A. W. Sims.
J. P. Slade.
H. L. Smith.
John Stevenson, Jr.
N. S. Stockwell.
S. Stutz.
George E. Thackray.
William Thaw, Jr.
Robert M. Thompson.
M. Troilius.
James W. Tyson.
George R. Waite.
A. J. Walker.
Phillip Wallis.
J. D. Weeks.
J. A. Weimer.
S. T. Wellman.
Calvin Wells.
F. E. Weston.
William White, Jr.
William Wiley.
S. T. Williams.
J. P. Witherow.

# PAPERS

OF THE

# XLIVth (PITTSBURGH) MEETING.

*FEBRUARY, 1886.*

## *PROFESSIONAL ETHICS.**

BY J. C. BAYLES, NEW YORK CITY

(Presidential Address.)

*Gentlemen of the Institute:* Having availed myself somewhat liberally during the past two years of the latitude which is accorded the president in the selection of the topics presented in addresses from the Chair, I do not need to plead safe precedent as my warrant for devoting to the consideration of some of the questions in casuistry the answers to which will be found to furnish a basis for a code of professional ethics, the address which marks the conclusion of my service in the dignified and honorable office to which, through your unmerited favor, I have been twice chosen. It is not asking too much of the engineer that his professional morality shall conform to higher standards than those which govern men who buy and sell with no other object than the getting of gain. The professional man stands in a more confidential relation to his client than is supposed to exist between buyer and seller in trade. He is necessarily more trusted, and has larger opportunities of betraying the confidence reposed in him than is offered the merchant or the business agent. For the reason that he cannot be held to the same strict accountability which law and usage establish in mercantile business, he is under a moral obligation to fix his own rules of conduct by

* Since this address was written, my attention has been called to the fact that at the Bethlehem Meeting, in August, 1871, Mr. R. P. Rothwell presented a paper on "Professional Morality." This paper was not printed in the *Transactions*, or mentioned with Mr. Rothwell's other papers in the general index. If time had permitted, I should have selected another theme for discussion; but as Mr. Rothwell's able paper is found only in an early volume of *The Engineering and Mining Journal*, is not easily accessible, and has probably never been seen by the younger members, for whom my remarks were especially intended, it can scarcely be considered a prior publication of the Institute. So far as Mr. Rothwell's paper relates to the subjects treated in the above address, it presents views generally similar to those I have expressed, a coincidence which is not at all surprising. I have not, however, had occasion to quote his paper, as I am indebted to it only for the pleasure I experienced in reading it subsequent to the delivery of the address.

high standards and conform to them under all circumstances. Whatever the measure of his professional success—whether wealth and reputation crown his career, or disappointment and poverty be his constant and unwelcome companions—no taint of suspicion should attach to any professional act or utterance. Not only should he be able to write above the wreck of bright hopes, "Honor alone remains," but upon his great and successful achievements should it be possible for others to inscribe the legend, "In honor wrought; with honor crowned."

It is frequently and confidently asserted that at no time in the history of the world were the standards of business honor so high as now. The prevalence of dishonesty, in one form or another, is held to show simply that there is a great deal of moral weakness which is unequal to the strain to which principle is subjected in the keenness of business competition, and in the presence of the almost unlimited confidence which apparently characterizes commercial intercourse. The enormous volume of the daily dealings on 'Change, where a verbal agreement or a sign made and recognized in the midst of indescribable confusion, has all the binding force of a formal contract; the real estate and merchandise transactions effected on unwitnessed and unrecorded understandings; the certification of checks on the promise of deposits or collateral, and a hundred other evidences of confidence are cited as proofs that the accepted standards of business honor are high, and are kept so by public opinion. All of this is true in a certain limited sense; but the confidence which is the basis of all business creates opportunities for dishonesty which changes its shape with more than Protean facility when detected and denounced. The keenness of competition in all departments of professional and business enterprise presents a constant temptation to seize every advantage, fair or unfair, which promises immediate profit. It is unfortunately true that the successful cleverness which sacrifices honor to gain, is more easily condoned by public opinion than honest dullness which is caught in the snares laid for it by the cunning manipulators of speculation. The man who fails to deliver what he has bought, to meet his paper at maturity and make good the certifications of his banker, loses at once his business standing and is practically excluded from business competition; but if he keeps his engagements and is successful, the public is kindly blind to the agencies he may employ to depreciate what he wants to buy or impart a fictitious value to what he has to sell. Viewed from this standpoint, it may be questioned whether the accepted standards

of business morality are not, after all, those fixed by the revised statutes.

In so far as the engineer is brought in contact with the activities of trade, he cannot fail to be conscious of the fact that serious temptations surround him. Such reputation as he has gained is assumed to have a market value, and the price is held out to him on every side. It should not be difficult for the conscientious engineer, jealous of his professional honor, to decide what is right and what is not. He does not need to be reminded that he cannot sell his independence nor make merchandise of his good name. But as delicate problems in casuistry may mislead or confuse him, it is to be regretted that so little effort has been made to formulate a code of professional ethics which would help to right decisions those who cannot reach them unaided.

Standing in the presence of so many of those who have dignified the profession of engineering, I should hesitate to express my views on this subject did I not believe that many earnest and right-minded young men in our active and associate membership will be glad to know what rules of conduct govern those whose example they would willingly follow, and how one not a practicing engineer, but with good opportunities of observation and judgment, would characterize practices which have been to some extent sanctioned by custom. To those who have yet to win the gilded spurs of professional knighthood, but who cherish a high and honorable ambition, my suggestions are chiefly addressed.

An ever-present stumbling block in the path of the young engineer is what is lightly spoken of as the "customary commission"—a percentage paid him on the price of machinery and supplies purchased or recommended by him. That manufacturers expect to pay commissions to engineers who are instrumental in effecting the sale of their products, is a striking proof that the standards of business morality are quite as low as I have assumed them to be: that engineers do not unite in indignant protests against the custom and denounce as bribe-givers and bribe-takers those who thus exchange services, shows that the iron has entered the souls of many who may be disposed to resent such plain terms as those in which I deem it my duty to describe transactions of this kind.

The young man who is tendered a commission will naturally ask himself whether he can accept and retain it, and may, perhaps, reason somewhat in this way: "My professional advice was given without expectation of personal profit other than that earned in my

fee, and it expressed my best judgment. The price at which the goods were purchased was that which every consumer must pay, and was not increased for my advantage. The transaction was satisfactory to buyer and seller, and was concluded when payment was made. I am now tendered a commission which I am at liberty to accept or to decline. If I decline it I lose something, my client gains nothing, and the remaining profit to the seller is greater than he expected by that amount. If I accept it I do my client no wrong. If it is the custom of manufacturers to pay commissions, it must be the custom of engineers to receive them; and there is no reason why I should be supersensitive on a point long since decided by usage." This is false reasoning, based upon erroneous assumptions. Why do manufacturers pay commissions? Is it probable they make it a part of their business policy to give something for nothing? Is it not certain that they expect an equivalent for every dollar thus disbursed, and that in paying the engineer a commission they are seeking to establish relations with him which shall warp his judgment and make him their agent? It may be urged in the case of reputable manufacturers that they yield to this custom because other manufacturers have established it, and that in following the pernicious example they have no other object than to equalize the influences tending to the formation of professional judgment. This reasoning does not change in the least the moral aspects of the question from the manufacturers' standpoint; but what engineer with a delicate sense of professional honor could offer or hear such an explanation, without feeling the hot blush of shame suffuse his cheeks? The plain truth about the commission is that the manufacturer or dealer adds it to the selling price of his goods, and the buyer unconsciously pays the bribe designed to corrupt his own agent. Can an engineer receive and retain for his own use a commission thus collected from his client without a surrender of his independence, and, having surrendered that, can he conscientiously serve the client who seeks disinterested advice and assistance in the planning and construction of work?

It is possible, perhaps, for a man to dissociate his preferences from his interests; so, also, is it possible for one to walk through fire and not scorch his garments; but how few are able to do it! The young man in professional life who begins by accepting commissions will soon find himself expecting and demanding them, and from that moment his professional judgment is as much for sale as pork in the shambles. I counsel the young man thus tempted to ask himself,

Am I entitled to pay from the manufacturer who offers it? If so, for what? If not, will my self-respect permit me to become his debtor for a gratuity to which I have no claim? Does not this money belong to my client, as an overcharge unconsciously paid by him for my benefit? If I refuse it, can I not with propriety demand in future that the percentage which this commission represents shall be deducted in advance from the manufacturers' price, that my client may have the benefit of it? If this is denied, can I resist the conclusion that it is a bribe to command future services at my hands? Is not the smile of incredulity with which the dealer receives my assurance that I can only take it for my client and hand it over to him, an insult to the profession, which, as a man of honor, I am bound to resent?

Gentlemen, it is not true that custom sanctions the acceptance of commissions by the engineer. That it is much too general I will not deny, but there are very few men of recognized professional standing who would confess that they have yielded to the temptation and retained for their own benefit the commissions received by them. I do not hesitate to give it as my opinion that the acceptance and retention of a commission is incompatible with a standard of professional honor to which every self-respecting engineer should seek to conform. Those who defend it as proper and right and plead the sanction of usage, are not the ones to whom the young engineer can safely go for counsel and advice. The most dangerous and least reputable of all the competition he will encounter in an attempt to make an honest living in the practice of his profession, is that of the engineer who charges little for professional services and expects to be paid by those whose goods are purchased on his recommendation.

With equal emphasis would I characterize as unprofessional the framing of specifications calling for patented or controlled specialties, when to deceive the client bids are invited. I am well aware that it is easier to procure drawings and specifications from manufacturers than to make them. Many manufacturers are very willing to furnish them, but those who do are careful to so frame the specifications that they can secure the contracts at prices to include the cost of the professional work for which the engineer is also paid. There is nothing unprofessional in recommending a patented article or process, if it be, in the judgment of the engineer, the best for the purpose to be accomplished; but he will do it openly and with the courage of his convictions. The young engineer should, I think,

have no difficulty in recognizing the important difference which inheres in the methods by which a given result is accomplished.

In the relation of engineers to contractors, there is many a snare and pitfall for the unwary feet of the beginner. In superintending the construction of work the engineer may err on the side of unreasonable strictness, or on that of improper leniency. If so disposed he can involve any contractor in loss and do him great wrong, but it more often happens that the engineer is forced to assume a defensive attitude and to resist influences too strong for a man of average courage and strength of will, especially if his experience in charge of work is limited. He should enter upon the discharge of his delicate and responsible duties with a desire to do impartial justice between client and contractor. He is warranted in assuming that his judgment and discretion are his chief qualifications for the position of supervising engineer, and that all specifications are designed to be in some measure elastic, since the conditions to be encountered in carrying them out cannot possibly be known in advance. He should not impose unnecessary and unreasonable requirements upon the contractor, even if empowered to do so by the letter of the specifications. The danger, however, is principally in the opposite direction. Frequently the engineer has all he can do to hold the contractor to a faithful performance of the spirit of his agreement. He is bullied, misled, deceived, and sometimes openly defied. He must constantly defend himself against charges impeaching his personal integrity and his professional intelligence. The contractor can usually succeed in making it appear that he is the victim of persecution, and especially in public work he is likely to have more influence than the engineer with those for whom the work is done. It often happens that the engineer, defeated and discouraged, gives up the unequal battle. From that moment he is of no further use as an engineer, and if he remains for an hour in responsible charge of work he cannot control he rates his fee as more desirable than a reputation unsullied by the stain of dishonor. He has a right to decline a conflict for which he feels unequal, but he has no right to consent to a sacrifice of the interests of his client while he is paid to protect them. The questions of professional ethics arising out of the relations between the engineer and the contractor are much too complex to be decided by an inflexible rule of professional conduct, but the engineer cannot make a mistake in refusing to remain in responsible charge of work when, by remaining, he must give consent to that which his judgment tells him involves a wrong to his client.

With equal confidence may it be asserted that the engineer who secretly participates in the profits of the contractor, whatever the arrangement by which such participation is brought about, sacrifices his professional standing.

In making reports for contingent fees or fees of contingent value, the young engineer needs to exercise great discretion. This may be done without impropriety if done openly; but it is safe to assume that few opportunities will come to the young man with a reputation still to make, in which he can do clean and creditable work on any such basis. The engineer called upon to make a report for a fee in stock which depends for its value upon the effect of his report in creating confidence in the public mind, takes a fearful risk. However honest he may be, he places himself in a position in which the danger is obvious and the advantage uncertain. If, having a contingent interest in the result of his work, he is afraid to say so in his report, he may safely consider his position unprofessional and unsafe. Contingent fees are a delusion and a snare, and in making it a rule to refuse them the young engineer will be likely to gain more than he loses.

Reports intended to influence the public upon subjects concerning which the engineer knows himself unqualified to speak with authority, are to be classed with other forms of charlatanry. No man can claim infallibility of judgment, nor is this expected of the engineer, whatever his position; but those who pay for professional services have a right to demand that the man who assumes to speak as an expert shall have the special knowledge which will command for his opinion the respect of those who are well informed. I consider it unprofessional for the engineer to enter upon the discharge of any duties for which he knows he is not qualified, if for the satisfactory discharge of those duties he must assume a knowledge he does not possess. There has been an immense amount of unprofessional work done in the field of reporting, and many reputations have been blasted by a failure to draw nice distinctions in questions of professional honor. The young engineer cannot be too careful in this matter, and he will be fortunate if with all the prudence he can exercise he is able to avoid disaster. Of a professional reputation dependent upon the accuracy as well as the honesty of reports ordered and used for speculative purposes, one may say, as a marine underwriter lately said of an unseaworthy steamer, that he "would not insure her against sinking, from Castle Garden to Sandy Hook with a cargo of shavings."

In the matter of expert service in the courts I am disposed to speak guardedly. I see no reason why an engineer should not willingly go upon the witness-stand to give expert testimony if he has made proper preparation and has an honest conviction that his testimony can be given with a conscientious regard for the obligations of his oath as a witness. It is his duty and his privilege to defend his opinions, for the man without opinions which he is prepared to defend is worthless as a witness, and cannot properly be called an expert. But the conscientious engineer has no right to appear as a partisan of anything except what he believes to be the truth. If he finds himself parrying the questions of the cross-examination with a view to concealing the truth; if he realizes that he is a partisan of the side which retains him, and feels a temptation to earn his fee by falsehood, concealment or evasion, he can be sure that he is in a position in which no man of honor has a right to be. The abuses of expert testimony in civil and criminal suits are many and grave; its uses are perhaps exaggerated, and the witness stand is not an inviting field for the young engineer seeking a satisfactory career.

How far an engineer can properly use for his own advantage information gained in the discharge of duties of a confidential nature, is a question at once delicate and difficult. He cannot help knowing what he has learned, and his knowledge is his capital. He must be governed in this matter by the considerations which influence men of honor in the ordinary relations of life. Stock and real estate operations on confidential information which belongs to one's principles, are usually in violation of the simplest rules of professional honor. The manager who advises his brokers by telegraph and his principals by mail cannot, I think, claim to have a very delicate sense of right and wrong. He can judge his own conduct by the standard he would apply in judging like infidelity on the part of those employed by him.

In professional criticism of professional work it is easy to fall into ways which are wrong, morally and professionally. Criticism which is designed merely to advertise the critic serves no good purpose, and savors of charlatanry or something worse. Only a small proportion of the current critical literature of engineering has any other object than to help the critics to climb into notoriety on the shoulders of the abler and wiser men with whom they are brought into competition. I regard as unprofessional every effort to discredit honest and intelligent work, and every form of disguised advertising designed to give an engineer a greater prominence than

he has earned by successful and creditable work, or is entitled to claim by virtue of fitness for more than average professional achievements.

It is neither possible nor desirable to catalogue the unprofessional practices which in one way or another come to the notice of those observant of current happenings in the several departments of engineering. It is the contention of some that right and wrong are relative terms, applying to no action or line of conduct save as it is considered in relation to coincident and contingent circumstances. I will not deny that this may be true of all professional acts, but the impossibility of an arbitrary classification under the heads right and wrong, honorable and dishonorable, need not make it difficult for a man to formulate a code of professional ethics by which his own conduct shall be governed. There are certain broad ethical principles which never change. One is, that a man cannot serve two masters having conflicting interests and be faithful to each. Another is, that, however skillfully one may juggle words to conceal meanings or evade responsibility, if the intent to deceive is there he lies. Professional ethics are no different from the ethics of the Decalogue; they are specific applications of the rules of conduct which have governed enlightened and honorable men in all ages and in all walks of life. It is only when the moral sense is blunted, or temptation presents itself in some new and unrecognized form, that it is difficult to draw the line between right and wrong. I am aware that a delicate sense of honor often comes between a man and his opportunities of profit, and that a fine sensitiveness is rarely appreciated at its value by those who employ professional service. I know that in this busy world, men of affairs do not always stop to weigh motives, and that confident assurance often commands respect, while modest merit is distrusted. But I do not know that a man can sell his honor for a price and retain thereafter the right to stand erect in the presence of his fellows. I do not know that any engineer can make for himself a creditable and satisfactory career of whom it cannot be said that, whatever his mistakes or successes, his failures or triumphs, he has held his professional honor above suspicion.

## *THE GEOLOGY OF THE PITTSBURGH COAL-REGION.*

BY J. P. LESLEY, STATE GEOLOGIST OF PENNSYLVANIA.

THE Pittsburgh coal-region, if we regard the greatness of its extent, the picturesque beauty of its scenery, the salubrity of its climate, its relative situation on the Continent, the fertility of its soil, its unrivalled mineral wealth, and its magnificent system of natural transportation, is, perhaps, the most valuable spot on the surface of the planet.

Unlike the mythical Paradise inhabited by one man and one woman, it swarms with an abounding population, not living on the free gifts of nature without care and without toil, but expending its energies in unremitting labor, reinforced by the most elaborate machinery, in the production of everything which mankinds needs or desires; and unlike the Paradise of story from which flowed the four great rivers of the world in opposite directions, its own four rivers flow from the surrounding world into it, to constitute by their union the great highway water-course which divides the Northern from the Southern States. These rivers are the Monongahela, coming from the south, the Youghiogheny from the southeast, the Kiskiminetas from the east, and the Allegheny from the north. Uniting at the great city of Pittsburgh, they constitute the Ohio, which flows northwest and west, and then south and southwest, toward the Mississippi.

The Monongahela has been made navigable by a system of dams and pools; the Allegheny was navigable in its natural condition; the Kiskiminetas was made navigable by a State canal which has been vacated; and the Youghiogheny remains unnavigable.

Railroads supplement the deficiencies of the rivers, follow their banks, and share in the transportation for which the waters are not sufficient. Railroads and rivers concentrate at Pittsburgh; other railroads cross the highlands to the east and west; and branch roads ascend the side-valleys and ravines to the mines on the uplands.

The whole region is a scene of life; towns and villages dot its surface in all directions; hundreds of gangways open upon the sides of all the valleys, and deliver coal to trains of cars which move beneath them at water-level; furnaces and rolling-mills abound; hundreds of oil-wells furnish a flood of liquid fuel to pipe-lines

extending to retaining-tanks for foreign exportation, or the use of refineries; and the gas-wells are connected by similar pipe-lines with the iron-works, to which they descend from a distance of many miles. These are the greater features of the business life of the region; the minor features are made up of an infinite variety of large machine-shops, warehouses, and private homes. A vast community has organized itself by the spirit of the nineteenth century in a thousand forms of intelligence and force: Labor and capital, although holding each other mutually in check, are virtually and essentially co-indulgent and co-operative; and will undoubtedly in the long run, and at no distant day, educate each other into a common understanding and mutual respect. There seems to be no limit to the development of every kind of human life in the region; and while the population of the denser centers must continue to double in numbers every quarter of a century, the vast outspread of upland will always insure it comfortable sustenance, and become one of the gardens of the world, populous, prosperous, and beautiful to every eye; dependent, yet independent; a region of rural homesteads, dotted with towns and villages, with their own appliances of advanced civilization; while gradually, as the centuries elapse, collieries with deep shafts will be established in all parts of it, and the stories of Manchester, Sheffield, and Coventry, in England, will be repeated at their full value.

The sketch which I have just made with a few simple strokes is sufficient to justify the statement that the Pittsburgh region is unique in the United States; and I feel sure that every intelligent traveller in distant countries of the world will be disposed to call it unique upon the surface of the globe; for nature has here expended all her resources for the advantage of a human population, bringing together and bestowing upon the citizens of Western Pennsylvania in a combined form the various natural gifts for which separately her bounty has been celebrated in other regions.

It is my object in this paper to show that all this wealth of life and splendor of endowment is based upon the geological character of the region. If its underground constitution were not Carboniferous, and if this constitution were not characterized by the extraordinary horizontality and continuous outspread of the Carboniferous rocks, the city of Pittsburgh, with its surrounding towns and villages, mines, mills and furnaces, dams, pools and steamboats, fleets of barges, trains of railroad cars, oil-well derricks and gas-pipe lines, would have been merely a poet's dream, and not the great

reality in which its people glory. If, like London, it were built upon the tertiary formation, although by the sea, its commerce would have been small, and its development that of an ordinary inland town. If, like Paris, the surrounding country for many miles had been a Cretaceous plain, producing nothing but quarry-stone, artesian waters, and the marvellous forms of extinct animals, it would never, without a royal, imperial, or national court to give it eminence, have made a figure among the cities of the great republic, notwithstanding its ancient settlement and its admirable situation. But as things are, its incalculable wealth of coal, absolutely inexhaustible for several thousand years, has made Pittsburgh the envy of the business world, and is a sufficient guaranty for a destiny of inimitable magnificence in a not distant future. This region will be an empire of itself, as wealthy, as powerful as England, subsidizing all other countries for its own uses, and unassailable from all quarters of the compass.

I confine the statement to coal, because I look upon coal as the only permanent element of the story. Petroleum and natural gas, which for the moment play so distinguished a *rôle* in the history of the Pittsburgh region, are merely supplemental to its prosperity—a temporary, a fugitive condition to its wealth; and, although inseparable from the main features of the Carboniferous geology, yet to be treated entirely apart from coal in our forecast of the future. They make indeed a most important chapter in our description of the geology of the region; but that chapter will be seen in course of time to be merely an appendix to the book. They go together into the chapter; for oil and gas are but two aspects of one and the same substance, originally united and still in combination; the one a product of the other; but neither of them holding any natural relationship to coal. The oil and gas obtained from cannel-coal and the coal-shales are not the same as the oil and gas which spouts and roars from the bore-holes. The cannel-coal and coal-shales are themselves of a different nature from embedded bituminous coal, having been produced in a different way originally, and having a different internal constitution.

Moreover, although the Dunkard Creek oil and gas come from one of the rocks of the coal-measures, the oil- and gas-product of Western Pennsylvania at large comes from a great formation underlying all our coal-measures, one in which no coal-bed has ever been seen; and therefore, even if the oil and gas of that Subcarboniferous formation were not generated in the formation itself, and have as-

cended from a greater depth, they are still further removed from any relation to the coal-measures.

I take this opportunity to express my opinion in the strongest terms, that the amazing exhibition of oil and gas which has characterized the last twenty years, and will probably characterize the next ten or twenty years, is nevertheless, not only geologically but historically, a temporary and vanishing phenomenon—one which young men will live to see come to its natural end. And this opinion I do not entertain in any loose or unreasonable form; it is the result of both an active and a thoughtful acquaintance with the subject. From the time that Colonel Drake sunk the first well on the plains of Titusville, I have professionally participated in the history of the oil and gas developments, and believe myself to be familiar with whatever has been said and done in the premises; and there does not remain upon my mind a shadow of doubt respecting the practical extinction, in the comparatively near future, of that great commerce in oil, of which the people of Pennsylvania have foolishly taken so little advantage, when they might have accumulated from its sale in all quarters of the world a provision of moneyed wealth unheard of in the history of our race. The opportunity is indeed still offered; but it is steadily diminishing, and in a few years it will entirely pass away never to return again. For I am no geologist if it be true that the manufacture of oil in the laboratory of nature is still going on at the hundredth or the thousandth part of the rate of its exhaustion. And the science of geology may as well be abandoned as a guide, if events prove that such a production of oil in western Pennsylvania as our statistics exhibit can continue for successive generations. It cannot be; there is a limited amount. Our children will merely, and with difficulty, drain the dregs.

I hold the same opinion respecting gas, and for the same reasons; with the difference merely that the end will certainly come sooner, and be all the more hastened by the multiplication of the gas-wells, and of the fire-boxes and furnaces to which it is led.

The exhaustion of the mineral coal of the region, on the contrary, is a practical impossibility. Every cubic yard of coal may be taken as a ton. Every square mile of a horizontal coal-bed may be said to yield a million tons to every foot of coal-bed—that is, for a ten-foot bed, 10,000,000 tons; or, allowing one-half for waste, 5,000,000 tons. The Pittsburgh region has an outspread of the Pittsburgh coal-bed 50 miles long by 50 miles wide within the

limits of the State. In the northwestern part of this area, the bed is 2 or 3 feet thick, increasing in thickness eastward and southward to 6′ of good coal at Pittsburg, 10′ up the Monongahela, and 12′ up the Youghiogheny. What the thickness of the bed may be underneath the uplands of Washington and Greene counties we now know by the new gas-wells. It maintains its thickness in that direction. An average of 8 feet for the whole region looks like a fair one. This gives 8,000,000 tons to the square mile, and there are 2500 square miles. Allowing one-half of the area to be interval, separating outcrops, we have then 10,000,000,000* tons remaining in this one coal-bed. Allowing 50 per cent. for pillars, bad mining, and waste of all kinds, we may set down its coal available for market in the future at 5,000,000,000 tons.

The Pittsburgh bed was mined in 1884 to the extent of about 11,000,000 tons. At this rate the bed would last nearly five hundred years. But, of course, the rate will rise steadily. The output of the Monongahela slackwater in 1884 was double what it was ten years before. If it goes on doubling every ten years the output of the Pittsburgh bed will reach the rate of the British coal trade, say 200,000,000 in about forty years from now; and were the doubling of the rate to go on still, the bed would be exhausted in about fifty years from now. But such calculations are evidently ridiculous, especially in view of the growing competition of other coal-beds and other coal-regions of the United States. No rate of increase in the output of coal from the Pittsburgh bed will exhaust it in less time than many centuries; of this we may be perfectly sure.†

It may be interesting to hear that in 1884 the output from the Pittsburgh bed was about 60 per cent. of the whole bituminous coal production of the State, and about 33 per cent. of the shipments of anthracite.

The coal-measures of the Pittsburgh region are about 2000 feet thick, and contain at least fifteen workable beds, which may be considered persistent and recognizable. Five of these beds lie higher than the Pittsburgh bed; the rest of them many hundred feet lower. Those above the Pittsburgh bed occupy smaller areas; and those below it spread much farther through the counties of northwestern

* Dr. Chance calculated it by areas, and obtained a total of 10,438,800,000 tons.

† The use of natural gas may seriously affect the advance of the rate for some years to come, and, perhaps, permanently, by introducing the use of artificial gas afterwards.

Pennsylvania. The whole series, therefore, lie upon each other like layers of a sea-shell, smaller and smaller from the lip of the shell back to its hinge; with this difference, that the uppermost coal-bed was the last created, whereas in the case of the sea-shell the largest layer is the last secreted. Thus, while the order of size and the parallelism of the edges of the layers is the same in both, the order of time is reversed. In consequence of this arrangement a bed 3 feet thick at the top of the series occupies an area and produces a gross total of merchantable coal only one-twentieth part of a bed 3 feet thick at the bottom of the series. Taking into consideration also the great extension northeastward of the lowest beds, even into the northern tier of counties, two hundred miles from Pittsburgh, and also the indefinite limits of what we may call the Pittsburgh region, any exact calculation of the total amount of coal which it possesses is impossible. But it will practically answer the purposes of this general sketch to say that, while the Pittsburgh coal-bed itself will furnish 10,000,000,000 tons, all the other beds will furnish about 20,000,000,000, making a total of 30,000,000,000 tons.

The geological explanation of the shell-structure of the coal-measures, viewed as one formation, is simple enough; for it arises from the fact of an exceedingly gentle southwestern slope of the strata from the New York State line, down the Allegheny river to Pittsburgh, and so on, through Washington and Greene counties, into West Virginia at the southwest corner of the State. This slope is practically regular for 150 miles, and amounts to about $\frac{1}{8}$ degree, or about 16 feet to a mile. In other words, the lowest coal-bed at the base of the Conglomerate lies in Warren county just 2000 feet—and at Pittsburgh only 60 feet—above tide. We have good data for placing it under Washington at tide-level, and in Greene county, Jackson township, about 600 feet below tide-level. It falls, therefore, 2600 feet in 160 miles. All the other coal-beds and intermediate sandstones, shales, limestones, clay-ironstones, etc., follow the same rule, have the same slope. In obedience to this southwest slope their outcrop belts stretch crosswise northwest-southeast in a series of concentric curves, each one further south than that of the one below it.

If the region of Western Pennsylvania had been planed off to a flat surface and dead level at any given height above tide, it is evident that the outcrops of the coal-beds at the limits of their areas would have been as continuous as the lines of wood-layers in a plank planed by a carpenter at a low angle across the grain. Now,

the agent which has removed the northern portions of the coal-bed areas could be nothing else than the annual rainfall of millions of years throughout the geological ages which have elapsed since the uplift of the continent out of the ocean at the completion of the coal-measures. Therefore, while the rainfall is practically uniform, acting equally on all parts of the surface of a country, yet it establishes a system of valley-drainage subject to an infinite number of minute local irregularities; it follows that the northern edges of the several coal-bed areas have been broken up into isolated patches in the tops of the highest hills to the north of the main body.

Each coal-bed in the series exhibits this geographical feature, as the county maps published by the State Geological Survey show; and it is exhibited in a large way on the little vignette colored State map accompanying this paper.

On this little map two tints only are used; the one to exhibit the area of the Pittsburg bed, and the Monongahela coal series overlying it; the other to exhibit the underlying thousand feet of Barren-measures and Allegheny coal series down to the top of the Conglomerate. It will be noticed how broken up into patches and dots is the northern edge of each of these two tints. It will be seen how the solid outspread of the Pittsburgh coal-bed in Washington, Greene, southern Westmoreland and Fayette counties gives place in the vicinity of Pittsburgh to isolated patches and small disks of the bed, representing outlyers of the Pittsburgh bed held by high divides and superior hill-tops.

The map shows that the Pittsburgh bed and those above it have been preserved from the general destruction only in the southern part of the region. I say *preserved from the general destruction*, for the destruction has been enormous in extent as well as in quantity. The Pittsburgh bed is now practically confined to the region south of the Ohio River and to long narrow strips of country east of Pittsburgh. Formerly it extended much further north. This is not theory; for remains of it are mined in Indiana and Armstrong Counties; and the geological map of Allegheny County shows four or five small patches of it still remaining nearly up to the Butler County line, the last one being 12 miles north of Pittsburgh.* How much farther north the bed once extended we cannot say, because the country has been planed down to lower and lower rocks in

* The bed opposite Pittsburgh is 1050 feet above tide. In Emmet's Knob, near Wexford, its floor lies at 1360 feet above tide, which gives a dip on a due south line of 310 feet in 12 miles, or 26 feet in 1 mile.

that direction; but I have never heard an argument which seemed to me considerable against the former extension of the Pittsburgh bed and its companions of the upper productive coal-measures into the State of New York, and over Northern Ohio; nor do I see any good geological reason for scouting the idea that its original area crossed Lake Erie and Lake Ontario into Canada. In 1840 I first demonstrated the ancient outspread of the Pittsburgh bed across the Ligonier valley and Somerset county, and across the Allegheny and Great Savage mountains to and beyond Cumberland in Maryland, a distance eastward of 150 miles from Pittsburgh. It is undoubtedly represented in the highest summit of Broad Top mountain, at the corner of Bedford, Fulton, and Huntingdon counties; and I have no doubt that, when the geology of the anthracite region is made out in all its details, the Pittsburgh bed will be definitely recognized.

I am disposed to maintain that much of what has been published respecting the original limits of the coal-vegetation, and in favor of a popular view that the present terminal outcrops of the coal-beds range not far distant from their original edges, has been too little influenced by the whole array of known facts; in other words, has been too much influenced by the local limitations of the very lowest coal-beds, especially those of the conglomerate series, the coal-beds of Mercer county, and Trumbull county, Ohio, the Sharon coal more than all others. And yet this Sharon coal, lying at the bottom of the whole series, has a great extension across eastern Ohio, increasing in size westward to its present outcrop, from which I believe it once continued across the so-called Cincinnati anticlinal into the Indiana coal-field.

But whatever may be said of the lowest coal-beds, the character of the Pittsburgh and other upper coal-beds is such as to put it beyond doubt that they once had a quasi-continental outspread; for, by the time that these upper coals came into existence, all the original irregularities of the conglomerate floor had disappeared beneath a thousand feet of muds and sands, which must have resulted in a nearly dead level of immense geographical extent.

If these views be correct, the State of Pennsylvania possesses only 1 per cent. of the coal which once existed within her State lines. For, at the low estimate of 100 feet of total coal-bed-section, as an average, in all parts of the area, there were originally 4 million million tons, of which there now remain only 35,000 million bituminous, and between 10,000 and 15,000 million anthracite.

That is, for every million tons remaining in the State, 80 or 90 millions have been swept away into the ocean. Nor can the purposelessness of this stupendous waste of precious stuff, the very life-blood of the new civilization of mankind, be adduced as an argument against the facts of the case, seeing that mankind has successfully inhabited the planet many thousand years without the use of coal; and especially, seeing that the two grand laws of God's creation are evidently these—infinite productiveness and infinite waste.

The Pittsburgh region, at least, has no reason to complain of the laws of nature, for it has escaped while other regions have suffered.

The splendid mineral wealth of the Pittsburgh region depends—1, on the superior quality of the coal which has been preserved; 2, on the almost unlimited quantity of it within easy reach; and 3, on the exceptional facilities offered by the geological structure to mining operations; but not upon the size of the individual coal-beds. Of this fact I will speak first.

There is a coal-bed at Commentruy, in the south of France, 140 feet thick. The mammoth anthracite bed is in many places 60 feet thick; and other beds are 30 and 20 feet thick. But in no part of Western Pennsylvania is there a coal-bed exceeding 13 or 14 feet. The Pittsburgh bed, in the neighborhood of Connellsville and up the Monongahela, may be fairly stated at 12 feet; but it becomes 15 feet thick on George's Creek, in Maryland. At Pittsburgh it outcrops along the river bluffs at an elevation of 350 feet above the water, with a thickness of 8 feet, yielding 6 feet of good coal. The other beds of the Upper Productive Coal-Measures overlying the Pittsburgh bed (four of them in the over-column of 370 feet) seldom exceed 5 feet. The Washington or Brownsville bed, 150 feet still higher in the series, is as much as 11 feet thick in a few places, but is usually much reduced by partings, and has a general average of only $3\frac{1}{2}$ or 4 feet.

The same thing is true of the Lower Productive Coal-Measures, the three Freeport beds, the three Kittanning beds, and the three Clarion beds. The old Upper Freeport bed, which I first extensively studied in 1841, and was then disposed to compare for size and quality with the Pittsburgh bed, has here and there an exceptional thickness of 7′ to 12′; but its general average cannot be safely stated at more than $4\frac{1}{2}$′; for the minute survey of the area of this bed in every county of Western Pennsylvania by the various assistants of the Second Geological Survey since 1874 has shown it to be far more variable, both in size and in quality, than was

supposed at first; but where of maximum size and quality it is worthy to be compared with the Pittsburgh bed. It underlies the bed of the river at Pittsburgh about 300 feet.

The size of the coal-beds, therefore, in the Pittsburgh region is by no means remarkable; but this, instead of detracting from the wealth of the region, may be almost reckoned among its advantages; for the practice of coal-mining has established the fact that nothing better can be desired than a nearly horizontal bed 5 feet thick, mining operations in such a bed being the easiest and cheapest possible.

The quality of the coal of the Pittsburgh region, especially of the Pittsburgh bed, is A No. 1 on the scale of merchantable coals of the world. This is not said in the spirit of any odious comparison. There are coals in other parts of the world equal to it in every respect. The coal, for example, of the Hub vein of the Glace Bay colliery in eastern Cape Breton is quite like it in every feature. The resemblance between that mine and mines on the Monongahela and Youghiogheny rivers is almost ridiculous: the bed is of the same thickness; the plies are arranged in the same way; the chemical analysis is identical; and the mining operations are conducted on the same plan; so that a ship-load of that particular Cape Breton coal and a ship-load of Pittsburgh coal laid on the same wharf could not be distinguished from each other. Many of the English coals are like those of the Pittsburgh region. But all this goes for nothing, in view of the prime fact that the Pittsburgh coal-bed can be opened in hundreds of collieries along both banks of both rivers for many miles, and in all their valleys and ravines, its zig-zag outcrop being not less than 2000 miles long; whereas, the Glace Bay coal of Cape Breton has an exposure of only three or four miles upon a wave-beaten sea-coast, and an outspread inland of little more than a dozen square miles. To compare the Pittsburgh region with the Nova Scotia region would be manifestly absurd, the wealth of the one being a thousand times greater than that of the other.

In another important particular the Pittsburgh region has an eminent advantage. Its great bed lies mainly above the drainage-level of the country. The coals of England and Belgium lie almost entirely beneath water-level, and descend to such depths that, in the government statistics of the coal-reserve of Great Britain, a limit of calculation had to be adopted, at a depth of 4000 feet, beneath which general mining operations are not likely to be largely prosecuted.

At present nearly all* the mines of the Pittsburgh region drain themselves naturally, or are simply drained by trenches in the gangways, with here and there a siphon, into the open river-valleys of the country. The time will come when deep shafts will be sunk to the Pittsburgh coal-bed on the uplands between the Allegheny and the Ohio rivers in Washington and Greene counties; but this necessity is a thing of the distant future, and need not be taken into consideration. In like manner the Lower Coal-Measure beds along the Allegheny river, the Kiskiminetas, the Mahoning, the Red Bank, the Clarion, and their numerous side-streams, are mined on their outcrops, and drain themselves in a majority of cases. In other coal-fields there is an underground world of hidden and expensive labor; in this favored Pittsburgh region is an upper world of easy mining, exposed to view and served by natural transportation.

I have alluded to the first-class quality of the Pittsburgh coal. I now instance the prime factors in this quality: 1. The low percentage of ash. 2. The small amount of pyrites. 3. The excellence of the coke made from it. The ash varies between 3 and 5 per cent., and seldom exceeds 6 per cent. The sulphur in analysis ranges at below 1 per cent., rising, however, occasionally to 2 or 3 per cent. in hard specimens. The coal contains from 30 to 35 per cent. of volatile matter. When coked, allowing for waste, something over one-half its weight remains as a silvery, ringing, tough, and pure coke, preferable to any coke made from the coals of the Southern and Western States, chiefly on account of the absence of sulphur, but partly on account of some obscurely understood internal constitution of the coke, giving that special hardness adapted for holding up the burden in a high-stack furnace.

It must be understood that the Pittsburgh bed has not a monopoly of these qualities, for they are exhibited also by the best beds of the Lower Productive or Allegheny series, as is shown by the excellent coke made from those lower beds, for example, in Clearfield county.

An elaborate account of the Connellsville coke region, trade and methods of coking, may be found in Report L, pp. 41 to 145, published in 1876; and another in Report G, published in 1879, by the State Geological Survey.

---

* The exceptions are in certain stretches of the rivers and in the basins of Westmoreland and Fayette counties.

I will now give a short sketch of the geological formations of the Pittsburgh region, beginning at the top of the coal-formations, and taking them in order downwards to the oil-measures.

The highest pile of coal-measures has been preserved in Greene county, near the State line, where the upland summits have an elevation of 2000 feet above tide, and the bottom of the great conglomerate has settled down to the depth of more than 500 feet below tide. In this part of the region, therefore, we have the most complete expression of the original thickness of the formation. But the general statement already made with regard to the former *lateral expanse* of the coal-beds beyond their present geographical outcrops must now be made with regard to the former *vertical height* of the whole formation. For, as the formation has been eroded on its basset-edges, so it has been eroded at its top. Beds once existed which no longer can be found; but we do not know their number nor thickness; so that we do not know at what height in the air above Greene county lay the last coal-measure. Were we to judge the case merely from the enormous amount of erosion which has taken place in Middle Pennsylvania (to the extent of 25,000 feet at Birmingham in Blair county, and at least 30,000 feet at Harrisburg) we might be led to suppose that the pile of coal-measures formerly rose thousands of feet above the highest hills of Greene county. But if that were in any sense a fact, we might have to call the lost strata by some other name than that of coal-measures; for in Europe a great formation overlies the Coal-measures proper, called the Permian, about which a great discussion has gone on, as to whether it should be included in the coal-formation. The discussion is based upon the character of the fossil forms, and is, therefore, confined to geologists desirous to systematize the nomenclature of our science. It is a discussion of not the least importance to those who busy themselves only with the order, character, and mineral value of the coal-formation. Its difficulties spring chiefly from essential differences between botany and zoology; but it is now generally granted that if any kind of fossils can settle the age of a formation, animal forms are better than vegetable forms for that purpose. Plants strongly resembling those fossilized in the Permian strata of Europe have been collected from the upper rocks of Greene county and the neighboring district of West Virginia by Professors Fontaine and White, who figured and described them in one of the volumes of our reports (PP, 1880). But on the other hand, animal remains from the upper coal-measures of our State have not been numerously

collected and described; but what is known of them would show that these rocks are a part of the coal-formation.

By whatever name we may choose to designate the highest known beds of the Pittsburgh region, whether Upper Carboniferous or Lower Permian, or, as some would compromise the case, Permo-carboniferous, the matter of interest to us is the great fact that we have been robbed of a greater or less thickness of overlying strata, by erosion, since the rise of the continent out of the sea; and that we shall never know what were the last and highest deposits made in the sea immediately before that great event took place. If the climate of our part of the world had been absolutely dry, like the great plains of the far West, or the desert of Sahara, the whole pile to the top would have been preserved for our observation; the history of the Palæozoic age would have been complete to the end of the last sentence of its first chapter; and, in order to turn the leaf to the first sentence of its second chapter, we should have had merely to transfer our attention to the New Red region of eastern Pennsylvania, and begin the story of the Mesozoic age with the conglomerate beds which cross the Schuylkill at Norristown and the Delaware at Trenton. As it is, at least one page of the Palæozoic chapter has been torn and lost, never to be recovered. There is no break in nature of such a kind as to allow an interval of deposits. Erosion goes on continuously, even during the operation of the greatest and most radical disturbance of the relations of land and sea. Whether our part of the continent rose by a single impulse, or by a succession of paroxysmal uplifts, like those which are still carrying up the Pacific sea-coast to higher and higher elevations—whether the estuary of the Mesozoic New Red was depressed at the same time with the rise of the interior country, or whether that estuary was subsequently formed, by the erosion of the Palæozoic limestones—whether the Mesozoic estuary had its full dimensions, or being first merely an incipient creek lying close along the shore of the Azoic seaboard belt, afterwards grew in width by the gradual settling down of its bed northwestward along the line of a profound fault—it remains all the same true, that as soon as the last bed of the Permo-carboniferous formation was lifted above the waters, there immediately succeeded deposits elsewhere, in some part of the Mesozoic region (although it may be impossible to fix the localities) put or left under water on the conclusion of the Palæozoic age. The people of the Pittsburgh region, however, may be interested to know that the termination of the coal age was no

calamity for them, in the sense of diminishing in any degree the wealth of their region; for long before the end of the coal age, coal-beds of any importance had ceased to come into existence.

The large subdivisions of the coal-formation were called by the geologists of the First Survey by the following names, which so clearly describe their characters, that they will probably hold good to the end of time:—

1. The Upper Barren Measures, which have been divided by the Second Survey into an upper Greene County group, and a lower Washington County group, the bottom of the whole being the massive Waynesburg sandstone.

2. The Upper Productive or Monongahela River coal-series, containing the Waynesburg, Uniontown, Sewickley, and Redstone coal-beds, and the Pittsburgh coal-bed at its base.

3. The Lower Barren Measures, from the Pittsburgh coal-bed down to the base of the Mahoning sandstone, containing no workable coal-bed in the Pittsburgh region.

4. The Lower Productive or Allegheny River series, subdivided by the First Survey into three groups, accepted by the Second Survey, viz.: The Freeport group at the top, with three coal-beds; the Kittanning group in the middle, with three coal-beds; and the Clarion group at the bottom, with three coal-beds. But of these nine coal-beds, not more than two, or at most three, are anywhere found workable directly over one another, so great is their variability in size and quality from mile to mile in any direction.

5. The Pottsville Conglomerate series (No. XII.), subdivided into three sandstone formations, upper, middle and lower, separated by shales containing small beds of coal, thin limestones, and poor iron-stones, and resting on the Sharon bed, celebrated for its furnace or block-coal; a bed which widely spreads itself through Ohio, but is worthless in Pennsylvania, except in Mercer county.

The First Geological Survey recognized this as the bottom of the coal formation; and it practically remains so to this day; there being no workable bed of coal in Pennsylvania from the Sharon coal down through 25,000 feet.

The Second Geological Survey, however, has seen good reason for applying the term Coal-measures to several thousand feet of rocks underlying the Pottsville conglomerate in middle Pennsylvania; for a group of coal-beds crop out at least 600 feet beneath the conglomerate along the face of the Allegheny mountain; and one or two of these beds are now being tested for mining purposes, in a

very thorough manner, in a ravine on Tipton run, near Altoona. Geologists regard the trial with great interest, as the result will either prove or disprove the possibility of these generally worthless coal-beds being of real commercial value in isolated spots. Such a spot was once mined on Tom's run, a branch of the New River in Virginia. Another such spot has been tested at Duncannon in Perry county, where one of these beds seemed promising but proved worthless. Another such spot has been tried, with the same want of success, at Mt. Patrick, higher up the Susquehanna. Where the Sideling Hill tunnel of the East Broad Top railroad cuts this group of beds, they number nineteen in all, and all of them are worthless. But when we go far south into Tennessee and Alabama, we find at this low geological horizon a considerable number of valuable coal-beds, constituting in fact the real productive coal-measures of the Gulf States. Our nomenclature must, therefore, be modified; and the coal-formation, as a whole, must be extended downward to include the Mauch Chunk red shale formation No. XI. and the Pocono sandstone formation No. X.

It may be asked whether these worthless No. X. coal-beds spread beneath the Pittsburgh region; and if so, at what depth. The answer is, that they are represented by one or both of two black shale intervals in the Pittsburgh Boyd's Hill gas-well-record (994′ to 1076′, and 1405′ to 1558′), *i.e.* between 841′ and 1435′ beneath low-water level in the river. This represents a depth of between 1200′ and 1800′ beneath the Pittsburgh coal-bed. In the center of the State the No. X. coals occupy the interval between 3000′ and 3313′ beneath the Pittsburgh coal-bed.

It is evident that the lower members of the carboniferous system thin to less than one-half, in a direction westward, in the distance of 100 miles between Huntingdon county and Pittsburgh. We may therefore expect to find other great formations doing the same.

On the Susquehanna river above Harrisburg the eleven palæozoic formations from the top of the Pottsville conglomerate No. XII. to the top of the Potsdam sandstone No. I. measure at least 26,000 feet.* These same formations measure along the Ohio river above Cincinnati less than 3500 feet.† Pittsburgh is midway between these eastern and western outcrops. If the rate of westward thinning were regular, we could say with some confidence that a well bored at Pittsburgh would strike the Potsdam sandstone No I.

* Report F, 2.

† Geol. Ohio, I.

at a depth of about 15,000 feet. But we know that the thinning goes on very rapidly between the Allegheny mountain and Pittsburgh in the Lower Carboniferous and Devonian strata; therefore it is quite possible that the Potsdam may lie not much deeper than 10,000 feet beneath Pittsburgh.

At all events, the palæozoic system as a whole is not half as thick in the Pittsburgh region as it is along its southeastern outcrop in eastern Pennsylvania and northern New Jersey.

Fifty years ago, by the combined labors of the four geological surveys of Pennsylvania, Ohio and New York, it became known that as a rule all the shale- and sandstone-formations are thicker and coarser in middle Pennsylvania, and grow thinner and finer northward into New York, westward into Ohio, and south-westward into middle and West Virginia; that the great limestone-formations at the bottom of the series increase in thickness for a certain distance into western Pennsylvania and then diminish; and that the thin limestone-beds in the upper parts of the series increase in thickness from the Susquehanna river all the way to the Mississippi, and south-westward into the Gulf States. But the preponderance of Palæozoic sandstones and shales over limestones is so great that the increase of the latter does not balance the decrease of the former; in consequence of which the whole Palæozoic system grows thinner and thinner from Harrisburg to Pittsburgh and Cincinnati, and from Harrisburg to Buffalo. In some of its details the thinning is astonishingly rapid. For instance, the Mauch Chunk red shale No. XI., 3000 feet thick in Schuylkill county, is only 200 feet thick in the Allegheny mountain, and does not certainly exist at all at the New York and Ohio State lines. The great Upper Devonian Old Red sandstone formation No. IX. and the still greater Lower Devonian Formation No. VIII. (Chemung, etc.), which taken together measure 11,000 feet on the lower Juniata, crop out in middle and southern Ohio and along Lake Erie with a combined thickness of less than 1000 feet.

As Pittsburgh is 80 miles from the nearest Devonian and Silurian exposures along the Allegheny mountain, 110 miles from those on Lake Erie, and 160 miles from those around the capital of Ohio, we can know nothing precise about the respective depths of the Lower Devonian, Silurian, Siluro-Cambrian, Cambrian and Azoic formations beneath Pittsburgh, unless wells be bored 10,000 feet or more in depth.

Returning now to the coal-measures of the Pittsburgh region

proper, and considering their principal subdivisions in a descending order, the following short statement of their characteristic features will suffice for our present purpose.

### The Upper Barren Measures.

Nearly the whole upland of the two counties south of Pittsburgh has a surface composed of the eroded edges of the Upper or Greene County and the Lower or Washington County group, so decomposed by the atmosphere, and concealed by agriculture, as to make a comparison of the coal-beds in one place with another difficult.

The intercalated sandstones pass into shales, and the shales into sandstones, from township to township. The numerous limestones are thin and variable. The coal-beds are almost all too thin to be mined, and generally make no obvious mark upon the ground. The compiled column obtained by a close survey of the northern part of Greene county was found scarcely applicable in the southern townships; and differed materially from that in Washington county. But two salient features present themselves unmistakably:

1. The whole formation is evidently thinner in Washington county than in Greene county, and continues to thicken southward into West Virginia; so that it is probable that the highest preserved bed is in Greene county, in spite of the superior thickness of the whole formation in Virginia; for the thickening takes place in the body of the formation.

Its numerous limestone-beds seem to have been deposited in a long northeast and southwest belt; for if the geologist moves southward or southeastward into Virginia, he finds the limestones disappearing from his column, being replaced to a large extent by sandstones and shales.

Lithologically considered, the characteristic features of the Upper Barren measures as a whole are:

*a*. The absence of workable coal-beds.

*b*. The presence of seventeen different limestone-beds. The most persistent one of these, called the *Upper Washington limestone*, and adopted as the division-line between the two groups, is persistent throughout the region and may be called 30 feet thick. To the geologist this limestone is as important for identifying his sections of the Upper Barren measures, as the Ferriferous limestone has long been in the study of the Lower Productive Coal measures; although measurements made from its top upward in Greene county, and from its base downward in Washington county, cannot be so well relied

upon on account of the variable stratification of both groups already mentioned.

*c.* A number of sandstone deposits characterize the Upper Barren measures, the highest of which, near the top, is 50 feet thick; another, somewhat lower down, 60 feet thick, holds the thin Nineveh coal; and a third, called the Fish Creek sandstone, immediately underneath the last, is 100 feet thick. In the Washington group a sandstone deposit 80 feet thick contains in its middle the thin Jollytown coal-bed; and at the bottom of the group is a sandstone 30 feet thick. These sandstones mark the topography of the country strongly in different localities, but they cannot be used as good guides to the structure on account of the rapid local changes to which they are subject. In this they differ considerably from the great sandstones of the Lower Productive Coal-measures, especially the Mahoning sandstone, and the subdivisions of the Conglomerate; although these latter are themselves locally very variable. The contrast, however, must not be insisted on too strongly, considering the comparatively small area over which we can examine the upper sandstones, and the immense area over which and in every locality of which the lower sandstones have been minutely studied. If it were possible to replace the Upper Barren measures in their whole original outspread over western Pennsylvania, perhaps these sandstones also might be found to be, barring local variations, quite as widespread and persistent as those of the bottom series. On the other hand, the probability of their being actually more local is increased by the fact that the Upper Barren measures of which they form parts seem, when taken as a whole formation, more variable both in thickness and in the character of rocks than the underlying earlier deposits.

*d.* Another prominent feature of the Upper Barren measures is the red shale formation, near their top, which measures 80 feet in thickness, and colors the soil of the extreme highland of Greene county, suggestive of the Permian strata.

*e.* Although the term Upper *Barren* measures is justified by the fact that the thinness of the few coal-beds which exist makes them practically worthless, two of these coal-beds, lying near the bottom of the formation, are really valuable. The Washington coal-bed and the Little Washington coal-bed lie only 10 or 20 feet apart. In Washington county the upper bed is 10 feet thick and the lower bed 1 foot; a 10-foot sandstone parting them. Traced into Greene county, the big bed dwindles to 2½ feet and the little bed swells to 7 feet;

and there 18 feet of soft sandstone and clay separate them. What becomes of these two beds further south we do not know; but as oil- and gas-wells will undoubtedly be bored in great numbers in that region, we can only hope that if well-borers keep no other record they will in all cases obtain at least the relative positions and approximate thicknesses of these two important coal-beds. By reference to the colored geological maps of Washington and Greene counties, published by the Survey in 1878, it will be seen that the Washington coal-bed plays the same *rôle* on the upland that the Pittsburgh coal-bed plays in the valleys.

On these two maps the importance of the bed is recognized by figures before a W showing its calculated depth in feet beneath the present surface at a great many points. Similar figures before a P show the depth in feet from the surface down to the Pittsburgh bed; the distance from the Washington bed down to the Pittsburgh bed being about 500 feet.

It must not be supposed that the Upper Barren measures are confined to the country west of the Monongahela river. They formerly extended over Fayette and Westmoreland counties, and indeed over the whole state of Pennsylvania; for patches of them have been preserved in the anthracite coal-basins, near Pottsville, and near Wilkesbarre. The highest hills east of the Monongahela river, along the synclinal lines in Westmoreland and Fayette counties, of which I must presently speak, are capped by these Upper Barren measures. But while in Greene 1100 feet of them have been preserved (*i. e.* more than 700 in the Greene county group, and something less than 400 in the Washington county group), the greatest thickness of any of the patches left in Fayette county is only 660 feet. Their locations and sizes are shown on the colored maps of Fayette and Westmoreland counties published in 1877; and it will be seen by reference to the report of that year on those counties that the Washington bed on that side of the river has a maximum thickness of 10 feet; but with a character so extremely variable, and shale partings so numerous, as to make it nearly worthless.

The palæontology of the Upper Barren measures, when studied, will be very interesting. The uppermost (14th) limestone contains occasional fish-scales. The 10th limestone breccia has a shale roof with plants and occasional fish-scales. The 6th or large snow-white Upper Washington limestone is roofed by a black shale containing vast numbers of bivalve crustaceans and fish-scales, all well preserved, and is often crowded with the long slender leaves of *sigillaria*

*medardi* (?), as best seen at the tunnel east of Washington. Calamites are also abundant, but only a single fern leaflet (*Neuropteris*) was seen. In a middle dark band of this limestone great numbers of little bivalve crustaceans are well preserved; they are, however, common to all the limestones of the series. In the lowest fetid layer of this limestone are broken fragments of mollusks. The 4th or ferruginous limestone is rich in calcspar replacements of minute *Bellerophon* and *Euomphalus;* while branching *bryozoa* cover its weathered surfaces. A fish-tooth (*Diplodus?*) has been found in it, and a fine spine of *Ctenacanthus marshii,* 5 inches long. The 3d limestone has a black shale roof with many lamellibranch shells, and fish-scales, some of which are large *Rhizodus.* The 2d limestone has a black shale roof rich in bivalve crustaceans and fish-scales, with an occasional macreated leaf.

The total thickness of the Upper Barren measures as preserved is about 1100 feet.

### The Monongahela Series.

The total thickness of these Upper Productive Coal-measures is something less than 500 feet. Their sandstones and limestones outcrop along the hillsides of the Monongahela and Youghiogheny rivers and all their affluents, in bluffs and cliffs exposed to most satisfactory examination; and these outcrops are so bold and persistent that the study of the region is rendered as easy and simple as any geologist could desire. The Pittsburgh coal-bed at the base of the group; the Redstone coal-bed, 60 feet higher; the Sewickley coal-bed, 50 feet higher; the Uniontown coal-bed, more than 150 feet higher; and the Waynesburgh coal-bed, 100 feet still higher, have been mined or exposed by the pick in a thousand places. The order of the beds, first established in 1840, has remained unchanged under the long and minute examination made of them in the two first years of the present survey.

The overwhelming predominance in value of the Pittsburgh bed over any value that can be assigned to the four beds above it, has confined mining operations, and therefore practical explorations, to it. Hence, while we know in general, and to a great extent in particular, the character of each of the other four beds, there remains still much to be learned in detail respecting them. The names assigned to them speak for the several districts in which they reach their maximum size and quality, and where alone they have been to any extent mined. Each one in its own district is a valuable

coal-bed, ranging from 3 to 5 feet in thickness, and furnishing good coal; but, in other districts except its own, each of these four beds loses more or less of its practical value, and is neglected, except by here and there a farmer, who supplies his own wants and those of his immediate neighbors from its outcrop on his own land. For this reason these beds are sometimes mined when only 2 or 2½ feet thick; and it is by means of many hundreds of such local openings that our knowledge of the group has become so nearly complete.

The great feature of the Upper Productive Coal-measure group is its limestone rocks. So striking is this peculiarity, that the First State Survey, in adopting a nomenclature for the coal-measures, called the interval between the Sewickley and Uniontown coal-beds *the Great Limestone.* It consists, however, of three deposits: an upper limestone and shale, 20 feet thick; a middle sandy and shaly mass, 60 feet thick; and a lower limestone and shale, 50 or 60 feet thick. Between the Sewickley and Redstone coal-beds the Fishpot limestone is sometimes 20 feet thick; and between the Redstone and Pittsburgh coal-beds there is still another limestone which becomes 10 feet thick. It may be said, therefore, that nearly one-fourth of the Upper Productive Coal-measures consists of limestone. Variable as it is from district to district, this great limestone formation, which still occupies so extensive an area between the Ohio river and Chestnut Ridge, once extended eastward across the Ligonier valley and Somerset county into the Potomac river country; for a patch of it, preserved from the general destruction, may be seen capping the Salisbury ridge, in the upper valley of Castleman's river, between the Negro and Allegheny mountains in Somerset county; and its outcrops overhang the Pittsburgh bed far into West Virginia. I say nothing here respecting the nature and origin of these calciferous deposits, which occurred at intervals through the whole coal age; but I merely direct attention to the fact that a fine exhibition of the phenomenon can be studied by geologists among the collieries of the Pittsburgh region.

Another interesting feature of the Monongahela series is the great sandstone formation at its top, making the fine cliffs along the river at Waynesburgh. The rock is massive, soft, weathering to honeycomb surfaces, ornamented with natural scroll-work of curious patterns, and full of crevices and underground chambers, like Huston's cave in Cumberland township, Greene county; but up the side-valleys and down the river towards Pittsburgh, the formation changes

to shale; towards Virginia, it becomes conglomeritic and bears salt water in Virginia.

The plant-bed, under the Waynesburgh sandstone and over the Waynesburgh coal, has been made classical by the elaborate report P 2 of Fontaine and White, published by the Survey in 1880. It is the repository of the finest leaf-impressions obtained in the Upper Coal-measures.

Of the 107 species described in P 2 the larger number occur in the Waynesburgh plant-bed; their admirable state of preservation appears in the figures on the thirty-eight plates of the report. Where the plant-bed is absent the sandstone rests directly on the coal.

*The Uniontown coal-bed* is sometimes a cannel-shale, containing great numbers of fish-teeth and scales.

*The Great Limestone*, under it, is often very fossiliferous, a minute whorled shell (*Pleurotomaria*) being very abundant, but not easily detected except on the rough weathered surfaces. The lower layers are non-fossiliferous, but valuable for hydraulic cement. At the bottom of the mass lamellibranch shells are common.

*The Pittsburgh coal-bed*, at the base of the Monongahela series, has been sufficiently noticed already; but its gently undulating outcrop along the sides of the valleys, mostly in the cliffs overhanging the river, yet sometimes sinking beneath water-level, cannot be properly explained until I come to a description of the anticlinal and synclinal waves which disturb the otherwise general horizontality of the region. On the southern side of the river, opposite to the city of Pittsburgh, the line of openings in the coal-bed may be traced by the spectator at an elevation of 350 feet above low-water mark and 1050 feet above sea-level. Down the south bank of the Ohio the bed is 400 feet above the river-level, and gradually retires into Washington county. Ascending the Monongahela river, it stands at 360 feet above river-level at Braddock's field on the north bank; slowly slopes southward for 25 miles to near water-level at Houston station; then rises to Belvernon; passes beneath the river at Brownsville; makes its appearance again for a short distance at Fredericktown and Millsborough; is 185 feet beneath the bed of the river 16 miles from the State line; rises to water-level at Gray's Landing, and stands 370 feet above it at the mouth of Cheat river inside the Virginia border.

But I must proceed with the description of the next underlying group of 600 feet of strata: the Lower Barren measures, or Barren

measures proper of the First Survey, which I may call the Pittsburgh series; for all the hillsides in sight of us are made of the upper half of this series, and the lower half of it lies immediately beneath our feet.

### The Pittsburgh Barren Series.

This group has been constituted in two ways; by measuring from the Pittsburgh bed down sometimes to the top of the Mahoning sandstone, and sometimes down to the Upper Freeport coal-bed beneath it; a difference which has given rise to needless embarrassment and controversy, there being no geological rule agreed upon in such cases. Some geologists prefer to *terminate* a pile of deposits with a coarse rock, supposing it to be the best mark of some physical change in the condition of things. Others prefer to *begin* a new series of deposits with such coarse beds. I myself prefer to include the Mahoning sandstone in the pile of Barren measures, and to call the Upper Freeport coal-bed the top of the Allegheny river series; chiefly for the reason that we can then make the distance from one great coal-bed down to another great coal-bed the measure of an interval of time, during which no notable coal-beds came into existence in the Pittsburgh region. Of course, all such arbitrary subdivisions of the column of coal-measures stand good only for the district in which they are made, and lose their value when applied to other regions.

With this understanding I may say that the total thickness of the Barren measures is something less than 500 feet at the Virginia State line, about 600 feet in the Monongahela river country, and nearly 700 feet in some other parts of western Pennsylvania.

Thus constituted, the group includes four principal sandrock formations: the Connellsville sandstone, lying 50′ beneath the Pittsburgh coal-bed; the Morgantown sandstone, 150′ beneath the Pittsburgh coal-bed; the Saltsburg sandstone 350′ beneath the P. C.; and the Mahoning sandstone, at the bottom, divided into two by a little coal-bed, and varying as a whole between 70 and 110 feet. All three spread widely through the region, making the valley-sides steep and rugged with cliffs, dropping huge fragments into the streams, and keeping the geologist well aware of his horizon in the series. But these sandstones, like all rocks, although persistent as a whole throughout the region, locally break up and fine away into sandy shales, with outcrops more or less concealed. Each has its maximum development in some one district: the Morgantown being

named from its cliffs in West Virginia; the Connellsville, from its fine exposures at the base of Chestnut Ridge; and the Mahoning, 50 years ago, from its magnificent exposures along that creek in northern Armstrong and Indiana counties.*

The limestone beds of the Barren measures are chiefly near the top, under the Pittsburgh coal-bed, and over the Connellsville sandstone. On the Monongahela, at Lock No. 4, the Pittsburgh coal-bed rests upon a limestone, 25 feet thick, with others below it for a hundred feet. A limestone, 4 feet thick, with a little coal-bed over it, caps the Morgantown sandstone. Below the Morgantown sandstone, that is, 250 feet beneath the Pittsburgh coal-bed, lies the *Crinoidal limestone*, 2 to 4 feet thick, which has been found of so much utility in a geological study of the region, as a universal key-rock or base of vertical measurement. Small as it is, it is found at so many distant localities, and is so easily identified by its multitudes of crinoidal disks, spines and shells,† that it would be well for every mining engineer in the region, to become acquainted with it. Well-sinkers can use it in the same manner as they have grown accustomed to use the Ferriferous limestone in the oil-region. Its description may be found, with an account of the various localities at which it has been observed, in various volumes of Reports of Progress upon the counties of western Pennsylvania.

An equally remarkable thin *black limestone* occurs about a hundred feet over the Mahoning sandstone, which can be put to good use where the crinoidal limestone is absent or concealed.

As for the coal-beds of the Barren measures, taking the whole region into account, they amount to nothing; but, thin and poor as they are, and sometimes disappearing from view altogether, they seem to occupy regular positions in the column; this, however, cannot be absolutely demonstrated, because a connection between the numerous exposures is often impossible. The question is a purely theoretical one, and of no importance in a practical estimate of the wealth of the region. There is a little coal-bed usually within 15 or 20 feet underneath the Pittsburgh bed; another little coal-bed 50 or 60 feet beneath it; a third about 150 feet beneath

* The *Bakerstown sandstone*, 100 feet thick locally, makes the cliffs along the Ohio river in Reserve township, Allegheny county. It lies but a few yards beneath the Crinoidal limestone.—(Q, 24, 165.) The *Buffalo sandstone* makes huge cliffs along the streams in the country north of Pittsburgh. It is the upper member of the Mahoning sandstone.—(Q, 33, etc.)

† *Productus, Hemipronites, Spirifer, Athyris, Lophophyllum, Zeacrinus;* and *Chonetes* and *Nautilus* locally. (See K, p. 80.)

it; a fourth 350 feet beneath it; and a fifth 450 feet beneath it, just over the Mahoning sandstone.

Another feature of the column of Barren measures is a deposit of red, variegated, and bluish sandy shales, 100 feet thick, underlying the Morgantown sandstone. Although the strongly red layers of this shale formation form but a moderate part of it, they make a great mark upon the country, arresting the attention of travellers. Members of the Institute as they came from the East probably noticed these red shales where they are cut at the Pennsylvania railroad summit, a few miles north of the city. In many parts of the region the red color is not so noticeable; but in the district immediately surrounding Pittsburgh the red soil is a marked feature in the landscape.*

The most interesting feature of the geology of the Barren measures is their *oil-bearing sands*.† The Morgantown sandstone is the *first oil-sand* of the Dunkard Creek oil-region; and yet it lies only about 150 feet beneath the Pittsburgh coal-bed, and its outcrop, 50 feet thick, can be seen from the windows of the Monongahela House running along the bluffs of the opposite side of the river. The *Mahoning sandstone*, lying there between 400 and 500 feet beneath the Pittsburgh coal-bed, yielded most of the Dunkard Creek petroleum. Of course, the well-drillers were bound to find their "third oil-sand," and in searching for it struck the Freeport sandstone of the Allegheny River coal-series (there about 600 feet beneath the Pittsburgh coal-bed), then the Clarion sandstone, and then the Conglomerate. All these they called one sandstone; said it was 400 feet thick; and abandoned it because it yielded very little oil, or none at all. It is needless to say that, when they were at the bottom of their so-called third sand on Dunkard creek, they had not got within several hundred feet of the top of the real first oil-sand of the oil-regions.

## The Allegheny Series.

This series underlies Pittsburgh from a depth of 250 feet down to 620 feet. Its groups of rocks, coal-beds, limestones, iron-stones, shales, and sand-rocks, rising gently northward, make their appearance successively in the bed of the Allegheny river from Freeport

* Three red-shale horizons have been traced through Allegheny and Beaver Counties—one 100 feet beneath the Pittsburgh coal, another beneath the Crinoidal limestone, a third above the Mahoning sandstone (Q, pp. 306, 307).

† K, 391.

up to the mouth of the Red Bank creek. With a gentle westward rise they come to water-level down the Ohio river near Beaver, and make the country from there to the Ohio line. They outcrop along a wide east and west belt across Lawrence, Butler, Clarion, Armstrong, Jefferson, and Indiana counties, and so on to the Allegheny mountain.

The First Geological Survey recognized in this formation only six persistent coals: the Upper and Lower Freeport, the Upper and Lower Kittanning, the Clarion, and the Brookville beds. Wherever any coal-bed was noticed it was identified with one or other of these six beds; and if there were strong arguments against the identification the bed in question was looked upon as a local deposit of no classical importance.

The long and minute examination of Western Pennsylvania made by the Second Survey during the seven years from 1875 to 1882, resulted in proving that three persistent coal-beds must be added to the six already established; and thus the numerous supposed local deposits assumed their proper places. The classification of nine beds in three groups has been established: Upper, Middle, and Lower Freeport; Upper, Middle, and Lower Kittanning; Upper, Middle, and Lower Clarion. I have already said, however, that, while this classification holds good in all the counties mentioned, there is scarcely any one column where more than two or three of the nine beds are workable. The names adopted for the groups are taken from the districts where the beds were earliest known and mined; but the maximum exhibition of a bed will be found at other localities; and this fact has given rise to a considerable number of popular local names. Full information respecting each subdivision and the beds which it contains will be found in the numerous volumes of the reports of progress. I will only mention those which describe these coal-beds in the Pittsburgh region proper, lying between the range of Chestnut Ridge and the Ohio State line. These volumes are: H 4, H 5, H 6, Q, Q 2, Q 3, V, and V 2. In volume I 2 will be found a large number of well-records, many of which pass through the Lower Productive Coal-Measures, but give little information concerning them.

Respecting the coal-beds I have already said enough in speaking of the one best known, the Upper Freeport, in comparing it with the Pittsburgh bed. I need only add that the coal-trade of the Allegheny river comes from this lower coal-series, just as the Monongahela river trade is maintained by the upper coal-series.

The most striking feature of the series is the fact that it alone contains cannel coal-beds; *e. g.*, the great deposit in Jefferson county 12 feet thick and a mile or more in diameter; and the great deposit of cannel and black shales at Darlington in Beaver county, equally local in its character, and made celebrated by the large number of fossil forms obtained from it by the zealous scientific researches of the Hon. Mr. Mansfield, to whom the survey is so much indebted in the preparation of the volume of the Coal Flora (P).

Most of these fossil forms are plants; but large and beautifully preserved crustaceans (*Eurypteroids*) have been found there with them. These are described in a small separate volume, entitled Report P 3, published in 1884. The cannel coal-deposits specially characterize the Middle or Kittanning group of the series, as is also the case on the Kanawha river in West Virginia.

The First Geological Survey recognized but one persistent limestone in the Lower Productive measures; and this limestone became, early in the history of the survey, a key to the identification of the coal-beds above and beneath it over the entire region. It remains to this day the principal key for calculating depths to deposits as far down as the oil-sand group.

It still retains the name originally given to it, that of the *Ferriferous limestone.* The name was bestowed upon it to signify that it carried all the important brown hematite iron-ore deposits of western Pennsylvania; deposits which were mined so extensively that they furnished stock for between 50 and 60 charcoal furnaces, all of which have been long since blown out, or rebuilt on a larger scale to use these ores as mixtures with ores from Canada and Lake Superior.

The *Ferriferous limestone* at the bottom of the Kittanning group is double,* the upper part gray, the lower part blue, containing a considerable percentage of carbonate of soda. It is crowded everywhere with fossils, chiefly crinoids, and always in a fragmentary or drifted condition; nowhere does it present the aspect of a coral reef. It weathers in furrows, wavy and shrivelled. It varies in thickness between the extremes of 0 and 25 feet, and sometimes shows itself on the sides of the valleys in vertical cliffs from which masses as large as a house have broken off and slid down to the streams. Over it often lie from 20 to 75 feet of sandy shales. Wherever this is the case there is a layer of chert between the shales

* Sometimes still more subdivided (Q, 315).

and the limestone. The shales are also ferriferous, and contain nodules and often large balls of iron-stone. The brown hematite deposits are in pockets in the upper part of the limestone. The theory of the Survey was a natural one, that both the chert and the iron-ore are result of the descent of silica and iron in solution from the overlying shales into the limestone; and that, therefore, wherever the shales were argillaceous and ferriferous, there occurred a large deposit of ore without chert; that wherever the shales were very silicious, and not very ferriferous, there occurred a large deposit of chert alone; and wherever the shales were both highly silicious and highly ferriferous a particularly thick deposit of cherty ore would be found. To this was popularly given the name of *buhrstone iron-ore.*

The Second Survey greatly extended these observations, and its reports summarize the facts, with many local details of great interest. The course of geological science through the last forty years has established in all parts of the world the correctness of the theory that such deposits of brown hematite are due to the gradual solution and removal of limestone to make room for the precipitation of ore with a variable amount of solidified gelatinous silica. A very good discussion of this subject will be found in one of the reports of the Kentucky Survey. An application of the theory to the Leadville deposits in Colorado has just been published in the *Engineering and Mining Journal.* It will also be found discussed and illustrated in the volume of the reports of progress of the Survey T 4 on Centre county; and a description of it under different circumstances will appear shortly in a report of the Cornwall ore-mines in Lebanon county, in the annual report for 1885, now going through the press at Harrisburg.

The persistent limestone horizons of the Allegheny coal-series have been found by the Second Survey to be more numerous than was supposed. Almost every coal-bed of the series is now known to be accompanied by a limestone bed, not indeed everywhere, but in hundreds of localities. Each of these limestones has had a classical name assigned to it.

### The Pottsville Conglomerate (No. XII.).

I think I may stop here in my description of the coal-measures of the Pittsburgh region proper; for, the underlying Pottsville conglomerate, with its three massive sandstone subdivisions, its insignificant coal-beds, its small but remarkable fossiliferous lime-

stones, its worthless iron-ores, has a general outcrop belt so far to the north as to exclude it from the area of the Pittsburgh region proper. The top of the formation comes to the Allegheny river level at Brady's Bend, goes down again, reascends to form the cliffs at Parker, and then spreads right and left, rendering the Clarion region one of the rockiest in the State. It presents superb exposures up and down the Beaver, Connoquenessing, Neshannock, Shenango, and Mahoning rivers in Beaver, Lawrence, Mercer, and Butler counties. Eastward it rises steeply from under the Blairsville-Connellsville basin to the summit of Chestnut Ridge on top of which great masses of it remain in their original situation overlooking western Pennsylvania, and offering to artists a curious and picturesque scenery little known.*

## The Mauch Chunk Red Shale (No. XI.).

Beneath the conglomerate lies the red shale formation, No. XI., which can be studied by the members of the Institute from the railroad car windows while passing through the mountain gap of the Conemaugh above Blairsville, and the mountain gap of the Youghiogheny above Connellsville.

The valuable iron-ore of Uniontown, in Fayette county, lies at the top of the formation, and a thick calcareous mass forms its base. These are minutely described in Reports K 2 and K 3. I will only add, that this *siliceous limestone*, about 30 feet thick at Blairsville, is recognized as far east in Middle Pennsylvania as Trough creek, Huntingdon county, where it forms a group of beds from 12 to 15 feet thick; but when followed from Connellsville along Chestnut Ridge into Virginia, it is seen 80 feet thick on Cheat river, swelling into the great subcarboniferous limestone formation further south. To the west it reappears in Ohio and Kentucky, and develops into the five Archimedes limestone formations of the Mississippi River.

It is perfectly evident therefore that this *siliceous limestone* of No. XI. (the mountain limestone of England) is a continental deposit; that it must underlie the Pittsburgh region, and should be passed through by every deep well. The first demonstration of the fact was afforded by the Boyd's Hill well in the city of Pittsburgh which I described in Report L in 1876, discussing the applica-

* See my Sketches of isolated castellated masses of it, Elk Rock, etc., in Report L, pp. 4, 6.

tion of natural gas to the manufacture of iron. The section there given shows this limestone lying at a depth of 914 feet in the well, *i. e.*, 807 feet beneath the Union Depot, 761 feet beneath low water in the river, or 20 feet *below* mean ocean level at Hoboken (see Report N, p. 6).

Recently this limestone has been recognized in all the wells drilled in Washington County. I have a communication from Professor Alonzo Linn, of Washington and Jefferson College, giving an account of its microscopic constitution. I look upon Professor Linn's results as of the greatest importance for explaining the origin of such limestones, bringing them into the range of oceanic coral reef sand deposits, such as are now being made over immense areas in the Pacific Ocean. He finds the 80-foot *sand-lime* of the wells to resemble closely the No. XI. *siliceous limestone* of the Bolivar and Connellsville gaps.

### The Mountain Sand Group (Pocono No. X.).

This comes next, lying beneath river level at Pittsburgh at a depth of from 760 feet down to nearly 1600 feet. It represents the Pocono sandstone formation No. X. of eastern and middle Pennsylvania. It makes great arches of cliffs in the gaps of Blairsville, Johnstown, Connellsville, and Ursina. Between two and three thousand feet thick in the eastern counties, it is but 840 feet thick at Pittsburgh, and 650 feet thick in the Venango county region. It spreads westward and southward to its long outcrop in Ohio and Kentucky, where it is known as the Knobstone formation. I have already spoken of the group of thin coal-beds which it includes.

In the northern oil district the mountain sands hold no oil, but in the Butler oil district the third mountain sand has been productive. It there received the name of the first oil-sand, under the mistaken supposition that it was the same rock as the first oil-sand of Venango county. This caused a false identification of the real first Butler oil-sand with the second Venango oil-sand, and of the real second Butler oil-sand with the third Venango oil-sand. The objections of the Geological Survey to this identification were unheeded for a good while, until at length a trial-well was sunk deeper, and the third oil-sand of the Venango belt became the fourth Butler oil-sand. But still the *third mountain sand* is known in Butler county as the first oil-sand.

The first or uppermost mountain sand becomes very coarse northward, and appears as a great conglomerate in Warren and McKean

counties. In Warren county it was named in the first years of the Survey the *Sub-garland conglomerate*, and in McKean county the *Sub-olean conglomerate*, which name alone will be used in the summary geology of Pennsylvania which I am now preparing for the press. In the report on Mercer county, it was named the *Shenango sandstone* and the *ferriferous sandstone*, on account of the abundance of nodules of iron-ore which pervade it. It lies in the northern region only from 50 to 70 feet beneath the lowest division of the conglomerate (the *Olean conglomerate*), which makes the rock cities of McKean county, and is quarried at Garland station in Warren county.

Mr. Carll early made the important discovery that the *Olean* and *Sub-olean conglomerates* need never be mistaken for each other, if strict attention be paid to the shape of their pebbles. These are round or egg-shaped in the Olean, and flattish in the Sub-olean. It is an important geological fact that the pebbles in all the coarse sandstones from the Sub-olean *downward* are, as a rule, flat; and the pebbles of all the conglomerates and sandstones from the Olean *upward*, round. The cause of this distinction is obscure, but it must probably be sought for in the different character of the countries from which the two sets of deposits were brought. It may be due perhaps also to some physical change happening to the character of the water-ways along which, or shallow-water beds in which, they were deposited.

The oil-bearing *Berea grit* of the State of Ohio was at first doubtfully identified with the mountain sands. It now seems probable that it is the equivalent of the third mountain sand, or first Butler oil sand, and not of the Murraysville gas-rock, with which it has also been identified.*

### The Oil-sand Group.

This underlies the mountain sand group. Mr. Carll was the first to make it known that the first, second, and third oil-sands of Venango county form a single group, wonderfully regular in its total thickness of about 350 feet, and so persistent as a formation as to be everywhere recognizable. The importance of this scientific

* Professor White at one time identified the Berea grit with the Smith's Ferry oil-rock in Beaver County, but he has recently convinced himself, by combining the last investigations of Dr. Orton, State Geologist of Ohio, with his own, that the Berea oil-rock is identical with the Rochester oil-rock, 900 feet beneath the Sub-olean.

discovery in its practical applications to the wealth of the Pittsburgh region can hardly be over-estimated; and one may well be surprised at the amount of facts to be collected and the patience and skill in combining the facts to be exercised before so simple a proposition was discovered to be true.

The first oil-sand was struck in the Pittsburgh (Boyd's Hill) well, at 1435 feet beneath low-water river level, as a white pebbly sand-deposit, 112 feet thick, with slight show of oil, but flowing 4000 barrels of salt water per day. More than fifteen years ago it was struck at Leechburg on the Kiskiminitas, and a great rush of gas escaped from it which was afterwards utilized in the iron works. Recently it has become the *great gas-rock* of the Murraysville district east of Pittsburgh. It is now known to lie under Washington county at the same depth of 1800 feet beneath the Pittsburgh coal-bed. It is there called the Gantz rock.

The second oil-sand in the new Washington district is called the Fifty-foot, and the third oil-sand is called the Gordon rock. From the top of the Gantz down to the top of the Gordon is about 260 feet. In Venango county the interval from the top of the first down to the top of the third oil-sand varies between 260 feet and 290 feet.

Considering the great variations in the thickness of many Palæozoic formations, taken as a whole, and considering the infinite variability of the oil-sand group in the details of its internal composition, *i. e.*, the local thickness and quality of each of its three sands, which at numerous points spilt up into 4, 5, and even as high as 10 layers, it is certainly an astonishing and most important phenomenon to see the group extending for 100 miles with an even thickness of about 350 feet, and always reassuming its normal aspect of a triple formation.

It must not be supposed that the great gas-rock stands alone as the gas-producer. Every sand-rock which has yielded oil has yielded gas. The great gas-flows of the Mead, Harvey, Mahan and some other famous blowers come from the Third Mountain sand (1st Butler oil-sand). Hence, this rock received in Butler county the name of the *gas-sand*. In the new gas-development the First Oil-sand now is so called. On the other hand, the immense old blowers, the Delamater, the Burns and the Thompson, were fed from the third oil-sand (Butler fourth). The tremendous Wilcox gas-well of McKean county blows off, under a pressure of more than 400 pounds to the square inch, from a geological horizon

1000 feet still further down; and the steady old Fredonia well in New York delivers from a reservoir far lower still. In fact every oil-sand and every mountain sand has yielded more or less gas; and we have seen that even the Mahoning sandstone in the Barren measures yields gas in the Dunkard creek region.

We can reach but one conclusion, namely, that the whole underground of western Pennsylvania is more or less pervaded, permeated by natural gas; it is hardly necessary to add that the gas only sets itself free in notable quantities through bore-holes which reach the looser and coarser sandstone layers, through which it can move freely, in combination with its invariable associates, petroleum and salt water. The gas is undoubtedly evolved from the petroleum, being merely the more volatile elements of that fluid; and this is shown by the well-known fact that the petroleum held by rocks near the surface, from which, therefore, the more volatile elements have easily escaped into the air, is dark and heavy, or lubricating oil; while the petroleum obtained from great depths retains all its elements, no chance having been given to the more volatile to escape. The clay-luting of the under-world has been so nearly perfect, that is, the petroleum has been so nearly hermetically sealed, at great depths, by the filling in of rock cracks with clay, that even the naphthas have scarcely escaped.

I may here add, in parenthesis, that this is the argument which weighs most in my mind against one of the popular theories entertained by geologists, that all our petroleum has ascended to the oil-rocks from far greater depths in the lower formations or in the interior of the earth; for I confess myself unable to understand how the material could ascend 3000 feet or more from the Silurian or Lower Devonian rocks and there been arrested, unable to continue its ascent through the remaining one, two or three thousand feet to the surface. In addition to this capital objection, there is another, namely that it has never been shown by any one that hydrocarbons in the gaseous form, ascending from great depths, could be condensed, or in any way changed into liquid petroleum, and held in that form, ever after, by the porous sand-rocks. But it is not my intention in this paper to present theoretical considerations. I wish merely to give the salient facts of the geology of the Pittsburgh region. No doubt more valuable papers will be read at this meeting upon both gas and oil; and my assistance in the discussion will be needless. I therefore proceed to say a single word respecting the still lower

rocks, and then, after a short statement of the anticlinal structure of the region, I will conclude.

## The Lower Devonian Rocks.

Beneath the third oil-sand at Pittsburgh no oil is known to exist; but in the northern region of Warren county, and in Forest county, pools of oil have been struck at several points in the sandy beds of the great Chemung formation No. VIII. which lies next underneath. These are the Warren oil-sands. Far beneath them, again, that is say 1000 feet beneath the oil-sand group, lie the phenomenal Bradford oil-rocks, extending into the State of New York. What other members of the Devonian formations are repositories of oil is not known; but we have every reason to believe that, if any exist, they are notably local, and, therefore, hard to find; and that when found, they will make but a slight impression upon the future oil-production. This conviction is supported by the extreme irregularity of all the deposits of that age wherever they have been studied throughout middle Pennsylvania. They have been examined in literally ten thousand places without exhibiting persistent sands. Evidently, unless sand deposits are persistent over considerable areas, even if they be charged with petroleum, the quantity must be small.

Among these Lower Devonian formations are considerable thicknesses of black shale, no doubt blackened by petroleum; and in the Western States bitumen fries from their outcrops under the sun. Still lower down are great limestone formations, such as the Upper and Lower Helderberg and Niagara limestones, full of fossils, both vegetable and animal, and showing petroleum at their outcrops in a way to make it perfectly clear that it is the product of the decomposition of organic matter. This fact was recorded by Professor James Hall, forty years ago. And twenty years ago, I showed that the petroleum of the Conglomerate formation in eastern Kentucky was produced by the decomposition of fossil plants. The Canada petroleum, and the low petroleum of Kentucky, like the gas at Fredonia and Erie, are referable to strata which doubtless underlie Pittsburgh at depths of several thousand feet. I trust that the new deep well at Rochester will help us to a certain knowledge of their character and condition here.

## Irregularities and Anticlinals.

I have treated the geology of the Pittsburgh region as if all its formations lay perfectly flat or nearly so. But the exceedingly gentle slope from Lake Erie to Pittsburgh represents the northwestern side of a structural basin, the great Sixth bituminous coal-basin. Its dip was calculated with great nicety by the First Geological Survey, and found to be at the rate of one-seventh of one degree, or about 16 or 17 feet in the mile.

The more minute and extensive surveys of the last ten years have shown that this slope is not a perfect plane; but that it has minute local variations, not indeed appreciable to the eye, but recognizable by a spirit level; and many of these irregularities have been located on the maps by a comparison of the tide-levels taken at openings on individual coal-beds. It appears that they are in some way connected with irregularities in the original deposits; and this is shown by the lines of rock-sections; and also by the exceptional strong dips which are met with in mining the lowest coal-beds. I do not think that they can be connected with the great system of anticlinal and synclinal plications of middle Pennsylvania. I am disposed to assign them to quite another cause, namely, to a change in the bulk of each coal-bed, both during the growth of its vegetation, and still more after it had become covered and pressed down by overlying deposits. For it is well understood that a peat-bog while growing and lifting its back into the air above water-level, goes on compacting its lower layers by the weight of its upper layers; and it is a physical necessity that many hundred feet of rock upon a coal-bed must press it into a thickness only one-tenth or one-twentieth of the original thickness of the peat-bog. Our venerable botanist Mr. Lesquereux's investigations in Europe half a century ago established all these points, and demonstrated the origin of coal-beds; and he has recently given me a memoir to insert in the Annual Report of the Survey for 1885, which will be perfectly conclusive to every mind.

The Pittsburgh coal-bed where it is now 12 feet thick must have been originally as least 150 feet thick; or rather it represented that amount of vegetation. Consequently, any irregularity in the thickness of a coal-marsh must have been the cause of a settling of the whole column of stratified rocks above the coal-bed to different depths at different places in after-times. Now in the sum total of

the thicknesses of all our bituminous coal-beds, say 100 feet, we have a rude measure of the amount of settling of the whole column of coal-measures. While the total amount of compression would be by the law of compensation the same over the whole region, it would vary locally in proportion to the thicknesses of the coal-beds. If we calculate it on the basis of a compression of only 5 feet of peat to one foot of coal, we get a total descent of the top coal-measures through a vertical height of 500 feet. Of course the details of the operation must be elaborately worked out; but I wish here to state the principle upon which I think the greater number of local irregularities of stratification are to be explained.

A very different view however has to be taken of the larger anticlinals about 10 miles apart, in a direction from northeast to southwest, approximately parallel with the tremendous rock-waves of middle Pennsylvania. They belong evidently to that system, and have been produced by the same unknown cause. I say advisedly, unknown cause, for, although it is practically certain that these great rock-waves have been produced by a side-thrust, connected in some way with the Azoic range of the Blue Ridge; and although it is also certainly true that the South Mountain country has been shoved bodily northwestward towards Lake Erie a distance of between 10 and 20 miles, wrinkling the earth's crust in that direction, yet all we know of the phenomenon is its consequences, the position and form of the waves, their original enormous height, and their subsequent erosion. As to the agency which produced the side-thrust and lifted the anticlinals, fracturing some and overturning others, we know absolutely nothing. Nor will we ever know much about it until a true theory of the interior of the globe has been devised.

The First Geological State Survey laid down the lines of five great anticlinals in western Pennsylvania, which it numbered first, second, third, fourth, and fifth—the first being that of Laurel Hill; the second, Chestnut Ridge; the third, Blairsville; the fourth, Saltzburg. The fifth crosses the Allegheny river at Brady's Bend. The Negro Mountain anticlinal was not counted in the series because it belongs to Virginia, and loses itself against the Allegheny mountain in Cambria county.

Intermediate secondary anticlinals were also located by the First Survey; such as the viaduct axis in the first basin; a small anticlinal running through Ligonier Valley; and several others further west.

The Second Survey, however, has greatly enlarged the number of

these secondary anticlinals. It has demonstrated the fact that the great anticlinals are not perfectly continuous, but are broken into sections which lie slightly diagonal to one another; and that all the anticlinals of western Pennsylvania die down and rise again repeatedly. Some of the geological maps of the counties published by the Survey exhibit the anticlinal lines; but all of the anticlinals are carefully described and located in the text of the several volumes of the reports, a matter of great importance in fixing the limits of the coal-basins, and the direction of mining operations.

The first and second grand axes have dips so steep (from 10 to 30 degrees) that they lift the Subcarboniferous formation into mountains and separate the coal-measures into distinct basins. But in the Pittsburgh region proper, that is, between Chestnut Ridge and the Ohio line, the anticlinals are so low that a dip of 5 degrees either eastward or westward is rarely seen; and usually the dip is only 3° or 2° or less than 1°. In the district around Pittsburgh, where a coal-bed will rise or fall only say 100 feet in a mile, the location of the crest of an anticlinal becomes a matter of extreme difficulty; but it *can* be accomplished by a full and complete discussion of the levels above tide-water of all the mine-mouths in any given neighborhood, and by mapping the course of the underground workings. To this end the work of the Geological Survey is now being carried on; and a specimen of the work so done, an anticlinal map of the district between the Youghiogheny and the Monongahela rivers, will be published in the forth-coming report of 1885. On this map the *underground shape* of the Pittsburgh coal-bed is shown by colored contour lines, such as are drawn to represent the undulations of the surface of a country. Another larger map shows all the anticlinals that have been approximately located in the Pittsburgh region.

But now I come to the main point. Quite recently the location of the anticlinal lines in the Pittsburgh region has become a sort of popular mania, produced by a theory. The whole community interested in the subject of natural gas has been carried away by a theory. Practical men and theorists have apparently changed sides; the so-called theorists maintaining a conservative attitude; the so-called practical men becoming wild theorists. And the theory to which I allude is the anticlinal theory of gas.

Stated in few words, it is a theory that oil, being lighter than water, must rise to higher levels. If the application of this theory was confined to bottles no one would dispute it; the water in a bottle must collect at the bottom, the oil in the middle, and the

gas on top. But the earth is not a bottle. It has no great caverns in it. More than that, the arrangement takes place naturally under the pressure of only one atmosphere; while any arrangement of water, gas, and oil made at depths of a thousand or two thousand feet, must be made under pressures of from 100 to 400 pounds to the square inch.

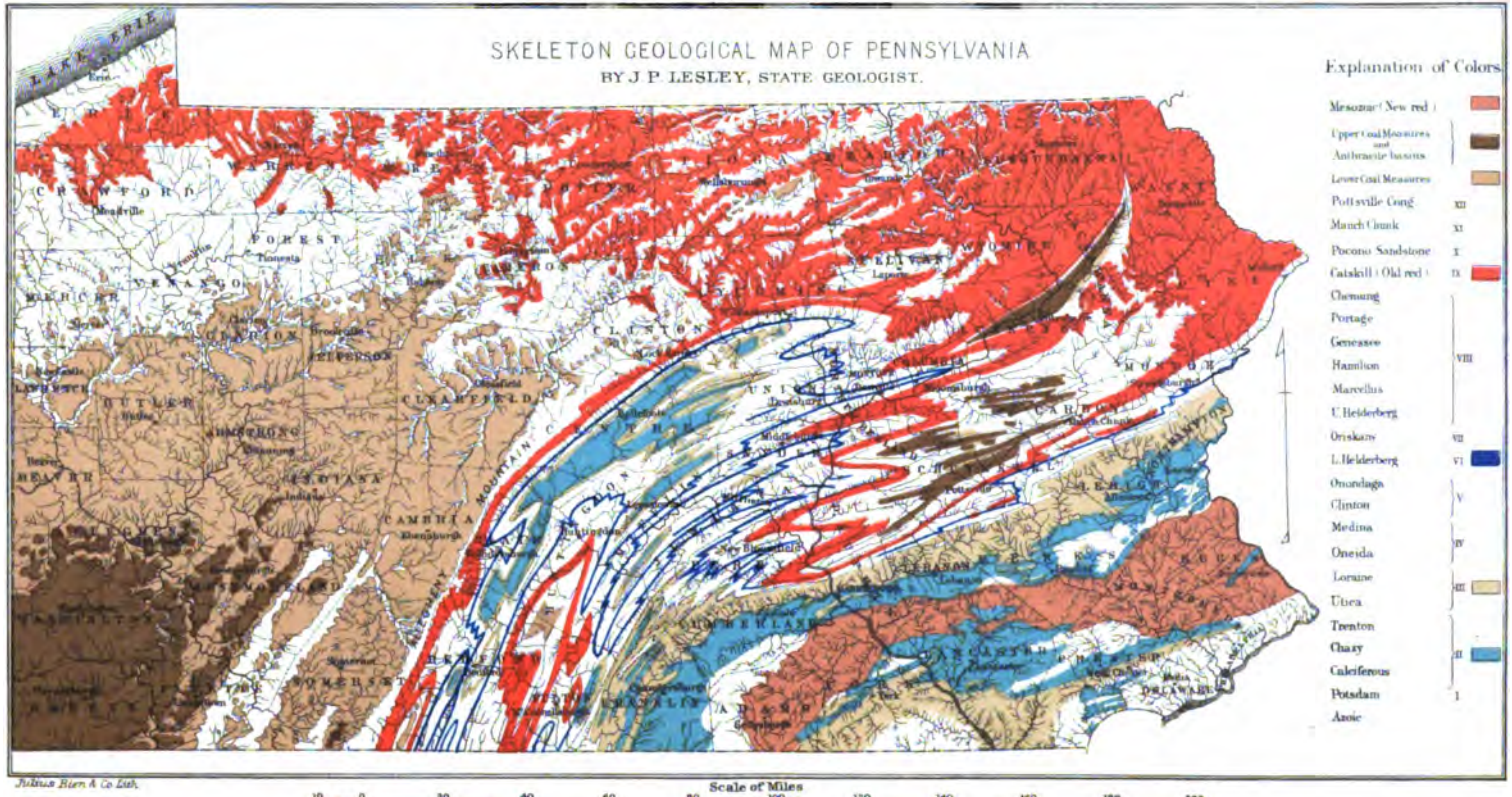
Mr. Carll recites a case where gas escapes at a pressure of 450 pounds to the square inch. It is impossible, therefore, that any arrangement of water, oil, and gas can occur in the deep oil-rocks, such as occurs in a bottle. If the anticlinals at Pittsburgh were like those in Middle Pennsylvania, where the rocks instead of lying nearly flat are turned up nearly vertical, the water, oil and gas at great depths, if they could exist at all, would remain practically mixed like the carbonic-acid gas in a soda-water fountain. It therefore seems to me irrational to assign any importance whatever to the extremely gentle anticlinals of the gas-oil region.

To this I add the important consideration that the movements of oil and water have been shown by actual practice to be governed entirely by the character of the rock in which they take place, and that they are effectually stopped at fixed geographical lines where porous rock changes into sandstones and sandstones into shales. And these changes of character in the rock itself have no fixed relation whatever to the anticlinal waves, which on the contrary cross them transversely or diagonally.

Finally, sufficient instances can be adduced to refute the popular assertion that great gas-wells are struck only on anticlinal lines; for some of them deliver gas from the bottom of basins. And on the other hand holes sunk on well-known anticlinal lines, and not far from good gas-wells, have yielded little or no gas at all.

As this whole subject is dealt with by Mr. Carll in his forthcoming report I will say no more; nor will I go into the subject of the statistics of the gas-yield, or its availability for practical purposes. These subjects will, probably, be presented to the Institute by experts in separate memoirs at this meeting. But I will add two opinions of my own, leaving them to stand for what they are worth.

1. As gas is a direct product of petroleum by spontaneous evaporation, the life of the gas-production will be limited by the amount of the volatile elements held in a definitely limited quantity of petroleum existing underground; and therefore those who are producing and using this enormously valuable mineral substance should,


SKELETON GEOLOGICAL MAP OF PENNSYLVANIA
BY J P. LESLEY, STATE GEOLOGIST.
Explanation of Colors
Mesozoic (New red)
Upper Coal Measures and Anthracite basins
Lower Coal Measures
Pottsville Conglomerate XII
Mauch Chunk XI
Pocono Sandstone X
Catskill (Old red) IX
Chemung
Portage
Genesee
Hamilton VIII
Marcellus
U. Helderberg
Oriskany VII
L. Helderberg VI
Onondaga
Clinton V
Medina
Oneida IV
Loraine III
Utica
Trenton
Chazy II
Calciferous
Potsdam I
Azoic
Julius Bien & Co Lith.
Scale of Miles
Scale of Kilometers

## *PITTSBURGH AND VICINITY—A BRIEF RECORD OF SEVEN YEARS' PROGRESS.*

BY WILLIAM P. SHINN, PITTSBURGH, PA.

IT is almost exactly seven years since the last previous meeting of the Institute in this city. In a paper on "Pittsburgh, its Resources and Surroundings," read at that meeting, I showed that Allegheny County had produced in 1878, "one-twelfth of all the pig-iron, . . . . two-ninths of all the rolled iron (except rails), over one-eighth of all the Bessemer and open-hearth steel, two-thirds of all the crucible blister and puddled steel, one-fourth of all the glass, one-eighth of all the coal, and one-sixth of all the pig-lead produced in the United States;" and the object of this paper is to show that, great as the record then was, it has been greatly surpassed since.*

### POPULATION.

In my former paper I expressed the opinion that the census of 1880 would show the population of Allegheny County to be in excess of 300,000. The census report made it 355,869.

The following shows the growth of the county in population from 1790 to 1880:

| | |
|---|---|
| 1790, | 10,309 |
| 1800, | 15,087 |
| 1810, | 25,317 |
| 1820, | 34,921 |
| 1830, | 50,552 |
| 1840, | 81,235 |
| 1850, | 138,290 |
| 1860, | 178,881 |
| 1870, | 262,204 |
| 1880, | 355,869 |

This makes Allegheny County, in 1880, rank sixth in population of the counties of the United States, whereas in 1870 its rank was ninth.

The population of Pittsburgh in 1880 was 156,389, being twelfth

* As in my former paper on Pittsburgh, read at the meeting in May, 1879, I am indebted to the American Iron and Steel Association, Mr. G. W. Cope, Secretary, for many of my statistics, and to Mr. Joseph D. Weeks, Secretary Western Iron Association, for valuable assistance rendered.

in the list of cities, while in 1870 its rank was sixteenth, and Allegheny City had, in 1880, a population of 78,682, ranking twenty-third in the list of cities.

Chief among the many industries of Allegheny County is the manufacture of iron in its various forms, of which the most notable increase since 1878 will be found in

## Pig Iron.

Owing to the deposits of block-coal in the Shenango and Mahoning valleys, lying from sixty to seventy miles northwest of Pittsburgh, the furnaces of those valleys furnished, at the time my former paper was written, by far the chief supply of pig-iron for consumption in the mills of Allegheny County.

The adoption of Connellsville coke as the blast-furnace fuel, even in furnaces located within the block-coal district, has changed all that; and by far the larger part of the pig-iron used in Allegheny County, is now produced within the limits of the county.

There are now seventeen blast-furnaces in the county, with a capacity for producing 750,000 net tons of pig-iron annually, and two more furnaces building, which will increase the annual capacity to over 840,000 net tons.

The furnaces are, in detail, as follows:

| Built. | Names. | Owned by. | Height. | Bosh. | Capacity Net tons. |
|---|---|---|---|---|---|
| 1859, | Clinton, | Graff, Bennett & Co., | 45 | 12 | 15,000 |
| 1861, | Eliza No. 1, | Laughlins & Co., | 60 | 17 | 60,000 |
| 1861, | Eliza No. 2, | Laughlins & Co., | 60 | 14 | |
| 1886,* | Eliza No. 3, | Laughlins & Co., | 60 | 17 | 30,000 |
| 1882, | Edith, | Manchester Iron and Steel Co., | 70 | 16 | 35,000 |
| 1865, | Shoenberger No. 1, | Shoenberger, Blair & Co., | 62 | 13 1-2 | 48,000 |
| 1865, | Shoenberger No. 2, | Shoenberger, Blair & Co., | 62 | 13 1-2 | |
| 1872, | Isabella No. 1, | Isabella Furnace Company, | 75 | 18 | 130,000 |
| 1872, | Isabella No. 2, | Isabella Furnace Company, | 75 | 20 | |
| 1872, | Soho, | Moorhead, McCleane & Co., | 65 | 19 | 40,000 |
| 1872, | Lucy No. 1, | Carnegie, Phipps & Co., Limited, | 75 | 20 | 130,000 |
| 1877, | Lucy No. 2, | Carnegie, Phipps & Co., Limited, | 75 | 20 | |
| 1879, | A, | Carnegie Bros. & Co., Limited, | 65 | 13 | 25,000 |
| 1879, | B, | " " " | 80 | 20 | 55,000 |
| 1879, | C, | " " " | 80 | 20 | 55,000 |
| 1881, | D, | " " " | 85 | 20 | 57,500 |
| 1881, | E, | " " " | 85 | 20 | 57,500 |
| 1886,* | F, | " " " | 85 | 20 | 57,500 |
| 1883,† | Carrie, | Pittsburgh Furnace Co., | 70 | 18 | 40,000 |

* Furnaces in progress.

† Formerly the Glasgow (Port Washington) furnace; removed to Pittsburgh.

The following table, compiled from the statistics of the American Iron and Steel Association, shows the proportion which the product of pig-iron in Pennsylvania bore to that of the United States, and the proportion which the pig-iron produced in Allegheny County bore to that of Pennsylvania and the whole United States respectively (all stated in tons of 2000 pounds), indicating the progress made from 1874 to 1885—twelve years:

| Years. | United States. | Pennsylvania. | | Allegheny County. | | |
|---|---|---|---|---|---|---|
| | Total Product of Pig Iron. Net Tons. | Pig Iron Made. Net Tons. | Per Cent. of U. S. Product. | Pig Iron Made. Net Tons. | Per Cent. of Penna. Product. | Per Cent. of U. S. Product. |
| 1874 | 2,689,413 | 1,213,133 | 45.11 | 143,660 | 11.84 | 5.34 |
| 1875 | 2,266,581 | 960,884 | 42.40 | 131,856 | 13.72 | 5.82 |
| 1876 | 2,093,236 | 1,009,613 | 48.23 | 128,555 | 12.73 | 6.14 |
| 1877 | 2,314,585 | 1,153,356 | 49.83 | 141,749 | 12 29 | 6 12 |
| 1878 | 2,577,361 | 1,342,633 | 52.09 | 217,299 | 16.18 | 8.40 |
| 1879 | 3,070,875 | 1,607,763 | 52.35 | 267,315 | 16.62 | 8.70 |
| 1880 | 4,295,414 | 2,083,121 | 48.50 | 300,497 | 14.42 | 7.00 |
| 1881 | 4,641,564 | 2,190,786 | 47.20 | 385,453 | 17.51 | 8.34 |
| 1882 | 5,178,122 | 2,449,256 | 47.30 | 358,840 | 14.65 | 6.93 |
| 1883 | 5,146,972 | 2,638,891 | 51.27 | 592,475 | 22.45 | 11.51 |
| 1884 | 4,589,613 | 2,385,402 | 51.97 | 487,055 | 20.42 | 10.61 |
| 1885 | 4,529,869 | 2,445,496 | 53.98 | 585,696 | 23 96 | 12.93 |

This table is very interesting and instructive, as showing the part taken by the Keystone State in that corner-stone of productive industries, the manufacture of pig-iron; and its most gratifying feature to the Pittsburgher, is the steady increase in both the quantity produced and the relative proportion of the National and State output made in Allegheny County—which has increased its proportion of the State production, from 11.84 per cent. in 1874, and 16.18 per cent. in 1878, to 23.96 per cent. in 1885; while its proportion of the United States output has gone up from 5.34 per cent. in 1874, and 8.40 per cent. in 1878, to 12.93 per cent., or over one-eighth of the whole, in 1885.

## Rolled Iron.

The number of rolling-mills in the county compares with the number in 1878 as follows, viz.:

| | 1878. | 1886. | Increase. |
|---|---|---|---|
| Number of mills completed, | 34 | 37 | 3 |
| Number of mills building, | 1 | 1 | — |
| | — | — | — |
| Number of common puddling furnaces, | 769 | 968 | 199 |
| Number Danks puddling furnaces, | 11 | 11 | — |
| Number Siemens puddling furnaces, | 10 | 30* | 20 |
| Total, | 790 | 1009 | 219 |
| Annual capacity in tons, | 500,000 | 600,000 | 100,000 |

The number of single puddling furnaces in the United States in 1884 (counting each double furnace as the equivalent of two single furnaces) was 5265. In Allegheny County 1009. The number in Allegheny County being 19.16 per cent., an increase since 1878 (when it was 17.70 per cent.) of 1.46 per cent.

The following table shows the amount of rolled iron (including sheets and nail-plates, and excluding rails) produced in the United States and in Allegheny County for each year from 1874 to 1885 inclusive:

*Total Rolled Iron, including Nail Plates.*

| Years. | United States. | Allegheny County. | |
|---|---|---|---|
| | Product of Rolled Iron. Net Tons. | Product of Rolled Iron. Net Tons. | Per cent. of U. S. Product. |
| 1874 | 1,110,447 | 274,625 | 24.73 |
| 1875 | 1,097,867 | 239,069 | 21.78 |
| 1876 | 1,042,101 | 247,943 | 23.79 |
| 1877 | 1,144,219 | 268,486 | 23.46 |
| 1878 | 1,232,686 | 282,333 | 22.93 |
| 1879 | 1,627,324 | 353,894 | 21.75 |
| 1880 | 1,838,906 | 389,107 | 21.16 |
| 1881 | 2,265,346 | 505,182 | 23.44 |
| 1882 | 2,265,957 | 430,627 | 19.00 |
| 1883 | 2,283,920 | 472,351 | 20.68 |
| 1884 | 1,931,747 | 410,457 | 21.25 |
| 1885 | 1,804,526 | 412,801 | 22.88 |

* 15 double = 30 single furnaces.

It will be seen that up to 1881 Allegheny County kept up its previous average proportion of the rolled-iron production, falling to 19 per cent. of the United States product in 1882, and recovering to 22.88 per cent. in 1885, and this in the face of the fact that this county has been very active in the substitution of steel for iron during the past seven years.

The Bulletin of the Iron and Steel Association points out that the proportion of Bessemer steel, rolled into rails, has declined from 85 per cent., in 1882, to 78 per cent. in 1883; to 72 per cent. in 1884; and to 63 per cent. in 1885; the difference or excess being used for other products in lieu of iron.

This indicates an increase in the substitution of steel for iron in other products than rails from 280,000 tons, in 1882, to 620,000 tons, in 1885, or 121 $\frac{4}{10}$ per cent. in three years.

Six of the rolling-mills have connected with them nail-mills, which produced:

| | | | |
|---|---|---|---|
| In 1874, | . . . . . | 561,995 | kegs of nails. |
| In 1878, | . . . . . | 441,013 | " " |
| In 1883, | . . . . . | 627,896 | " " |
| In 1884, | . . . . . | 459,512 | " " |
| In 1885, | . . . . . | 176,258 | " " |

## Iron Pipe and Tubing.

There are now five establishments in Allegheny County producing wrought-iron tubes and pipe, ranging in size from the smallest gas-pipe to 16 inches diameter. Their aggregate production is about 44 per cent. of the whole United States output, of which about 20 per cent. is produced by the National Tube Works at McKeesport. The present capacity of this great works is stated as 600 tons of pipe per day; and this is about to be increased by material additions to the plant. The advent of natural gas as a fuel has greatly increased the demand for pipe, and has also increased the advantages of the Pittsburgh pipe-mills, in consequence of which, one large works is about being removed from its present location to Pittsburgh.

## Wire and Wire Rods.

The Oliver & Roberts wire-drawing mill was rebuilt, after a disastrous fire, in 1882. Its annual capacity is about 45,000 tons per year. The same firm's wire-rod mill was started in 1884. The

mill takes a 4-inch 140-pound steel billet, and at one heat rolls it into a No. 5 wire rod. The annual capacity of the mill is about 25,000 tons.

## STEEL.

Pittsburgh stands as pre-eminently at the head of the crucible steel industry, as when my former paper was written, and has made very commendable progress in the production of pneumatic and open-hearth steel.

There are now within Allegheny County:

| | | |
|---|---|---|
| Crucible-steel works, | 12 | |
| Cementation works, | 1 | |
| Siemens-Martin works, | 5 | |
| Bessemer works, | 4 | 8 converters. |
| Clapp-Griffiths works, | 1 | 2 " |
| Total, | 23 | 10 converters. |
| *Building:* | | |
| Bessemer, | 1 | 2 converters. |

The seventeen crucible works have:

| | | |
|---|---|---|
| Siemens furnaces, | 44 | 1240 pots. |
| Coke holes, | 11 | 44 " |
| Total, | | 1284 pots. |

Of the crucible-steel works, eight have Siemens-Martin furnaces, of which there are in all thirteen.

The following table shows the production of crucible and of all other steel ingots in the United States, and in Allegheny County, from 1874 to 1885 inclusive, with the percentage of each produced in Allegheny County:

*Product of Steel Ingots.*

| Years. | United States. | | Allegheny County. | | | |
|---|---|---|---|---|---|---|
| | Crucible Steel. Net Tons. | Bessemer and other Steel. Net Tons. | Crucible Steel. Net Tons. | Bessemer and other Steel Net Tons. | Per Cent. of U. S. Product. Crucible. | Other Steel. |
| 1874 | 36,328 | 205,286 | 17,915 | 6,000 | 49.43 | 2.98 |
| 1875 | 39,401 | 397,174 | 22,942 | 15,498 | 58.23 | 3.89 |
| 1876 | 39,382 | 557,792 | 25,009 | 54,467 | 63.51 | 9.97 |
| 1877 | 40,430 | 597,542 | 24,747 | 82,401 | 61.21 | 13.85 |
| 1878 | 42,906 | 776,908 | 27,866 | 106,948 | 64.95 | 13.80 |
| 1879 | 56,780 | 990,726 | 40,142 | 130,781 | 70.70 | 13.21 |
| 1880 | 72,424 | 1,324,591 | 52,136 | 169,819 | 71.95 | 12.82 |
| 1881 | 89,762 | 1,689,150 | 61,256 | 247,345 | 68.24 | 14.64 |
| 1882 | 85,089 | 1,860,006 | 59,596 | 258,501 | 70.00 | 13.90 |
| 1883 | 80,455 | 1,793,904 | 59,128 | 346,402 | 73.45 | 19.31 |
| 1884 | 59,662 | 1,677,323 | 38,885 | 289,376 | 65.18 | 17.26 |
| 1885 | 64,511 | 1,852,839 | 42,139 | 364,905 | 65.32 | 19.69 |

From this schedule it will be seen that the crucible-steel production has varied, since 1878, from 65 per cent. to nearly 72 per cent. of the total United States product; and the production of pneumatic and other steel has advanced from 13.8 per cent. in 1878 to 19.69 per cent. in 1885, of the total United States product.

It may be noted here that of the U. S. production of Bessemer steel ingots, Pennsylvania produced:

| | |
|---|---|
| In 1882, | 55 per cent. |
| In 1883, | 63.1 " |
| In 1884, | 66.9 " |
| In 1885, | 65.2 " |

There are now two steel-rail mills in the county: the Edgar Thomson Steel Works, which commenced work in 1875; and the Homestead Works, which began in 1881.

There are two works making steel castings, from crucible, Bessemer, and open-hearth steel, while the only Clapp-Griffiths converter

plant in the country in operation, will be one of the attractions of this meeting.*

This plant (of Oliver Bros. & Phillips) consists of two converters, of which only one is being operated, with a productive capacity of 25,000 tons annually.

The Bessemer steel-works now completed and building, will, doubtless, increase Allegheny County's proportion of the United States product by 1887 to over 25, and, perhaps, to 30, per cent.

## Steel Rails.

The absolute pre-eminence of Pennsylvania in the production of steel rails is not generally understood; it is shown by the following schedule, and the growing importance of Allegheny County will also be recognized.

*Production of Steel Rails.*

| Years. | United States. | Pennsylvania. | |
|---|---|---|---|
| | Steel Rails. Net Tons. | Steel Rails. Net Tons. | Per cent. of U. S. |
| 1881 | 1,844,100 | 891,179 | 48.3 |
| 1882 | 1,688,794 | 850,908 | 50.4 |
| 1883 | 1,360,694 | 857,818 | 63.0 |
| 1884 | 1,144,851 | 775,872 | 67.8 |
| 1885 | 1,074,607 | 736,522 | 68.5 |

Nothing can more thoroughly demonstrate the advantages which Pennsylvania enjoys for the manufacture of iron and steel, as compared with the other States, than is shown by this increase in percentage during a time of depression such as the country has been passing through since 1882; the percentage of Pennsylvania, of the total output, having increased from 48.3 in 1881 to 68.5 in 1885.

## Glass.

Since my former paper was written, the glass industry of this county has received an important accession in the Pittsburgh Plate-

* Since this was written I learn that a second plant of two three-ton converters was started at Belleville, Ill., by Gen. Powell, on Jan. 21st, 1886, and is running very successfully.

glass works, located at Creighton Station, on the West Pennsylvania Railroad. It is supplied with all its fuel from a well of natural gas on the premises, and is rapidly taking the leading position in the plate-glass manufacture, heretofore held by the works at New Albany, Ind., which latter establishment will probably be removed to this county at no distant day, unless a supply of natural gas should be discovered in its vicinity. A second plate-glass works of large capacity is now building, a quarter of a mile north of the existing works at Creighton, and will be put in operation within a few months.

The following is a statement of the kind, number, and facilities of the glass-producing establishments in Allegheny County in 1886:

| Kind of glass made. | No. of works. | No. of furnaces. | Pots. | Tanks. |
|---|---|---|---|---|
| Plate glass, | 1 | 2 | 28 | |
| Window glass, | 11 | 22 | 212 | |
| Flint glass, | 27 | 46 | 482 | 2 |
| Green glass, | 6 | 7 | 70 | |
| Total | 45 | 77 | 792 | 2 |

The value of glass manufactured in Allegheny County in 1880 was 26.79 per cent. of the annual U. S. product, being four times that of any State outside of Pennsylvania, and it is probable that with the advantage of the natural gas-fuel, the proportion will be materially increased in the early future.

## Copper.

There are two copper rolling-mills, producing rolled and pressed copper, and one smelting-works, smelting Lake Superior ore.

The latter produces 300 to 400 tons of ingot copper per annum, while the production of the former is estimated as follows, viz.:

| | |
|---|---|
| Sheets, pressed bottoms, planished copper and bars, about, | 3,000,000 pounds. |
| Brass kettles, 75,000 to | 100,000 " |

## LEAD.

The following statement shows the United States production of pig lead for 1882, 1883, 1884, and 1885, with the amount and proportion refined in Allegheny County, in tons of 2000 pounds:

| States. | 1882. | 1883. | 1884. | 1885. |
|---|---|---|---|---|
| Colorado, | 60,988 | 70,800 | 72,600 | 53,500 |
| Utah, | 29,947 | 33,330 | 30,432 | 29,160 |
| Nevada, | 8,590 | 5,775 | 7,718 | 3,600 |
| California, New Mexico, etc., | 3,700 | 15,840 | 14,470 | 27,993 |
| Total desilverized, | 103,225 | 125,745 | 125,220 | 114,253 |
| Missouri and Galena, | 29,015 | 21,600 | 18,140 | 21,265 |
| Total U. S. product, | 132,240 | 147,345 | 143,360 | 135,518 |
| Allegheny County, | 14,700 | 15,200 | 16,700 | 22,000 |
| Per cent. of total, | 11.12 | 10.32 | 11.65 | 16.24 |

The production of refined lead in Allegheny County is all from the works of the Pennsylvania Lead Company. Their total output in 1878 and in 1885 compares as follows, viz.:

| | 1878. | | 1885. | |
|---|---|---|---|---|
| Production. | Quantity. | Value. | Quantity. | Value. |
| Lead, tons, | 12,508 | $1,010,640 | 22,000 | $1,766,000 |
| Copper matte, tons, | 211 | 18,592 | 200 | 12,000 |
| Silver, ounces, | 874,461 | 979,400 | 3,471,000 | 3,645,000 |
| Gold, ounces, | 4,369 | 96,118 | 7,000 | 140,000 |
| Total value, | | $2,103,710 | | $5,563,000 |

Indicating an increased value of output since 1878 of 164.5 per cent.

## COAL.

According to the report of Albert Williams, Jr., Chief of Division of Mining Statistics, etc., of the United States Geological Survey, the total output of coal in the United States in 1882 was, in tons of 2240 pounds, 87,083,134 tons, of which Pennsylvania produced:

| | |
|---|---|
| Of anthracite, | 29,120,096 |
| Bituminous, | 22,000,000 |
| | 51,120,096 |

being 58.7 per cent. of the whole.

Of the bituminous coal, Pennsylvania produced 38 per cent., while the product of Allegheny County was 4,033,548 tons, being, of Pennsylvania's bituminous product, 18.3 per cent., and of the total bituminous coal product 7.0 per cent.

## Coke.

The so-called "Connellsville coke" is manufactured, and the coal from which it is made is mined, in the adjoining counties of Westmoreland and Fayette, at an average distance of about sixty miles from Pittsburgh; but the trade is located at, and the works are controlled in, Pittsburgh, so that a statement of the Connellsville coke product is not out of place in this paper.

As showing the growth of facilities and product since 1878 the following is stated:

| | In 1878. | In 1885. | Increase. |
|---|---|---|---|
| Number of ovens, . . . | 3,668 | 10,832 | 7,164 |
| Product in net tons, . . | 1,075,000 | 3,250,000 | 2,175,000 |

The following table shows the total product in the United States, and the proportion thereof produced in the Connellsville region:

| Years. | U. S. Product. | Connellsville. | Per Cent. |
|---|---|---|---|
| 1880 | 3,338,300 | 2,205,946 | 66.08 |
| 1881 | 4,113,760 | 2,639,002 | 64.16 |
| 1882 | 4,793,321 | 3,043,394 | 63.50 |
| 1883 | 5,464,721 | 3,552,402 | 65.00 |
| 1884 | 4,873,805 | 3,192,105 | 65.50 |
| 1885 | 5,106,385 | 3,096,012 | 60.63 |

Here it is again noticeable that, while the other parts of the country gain relatively on Pittsburgh in seasons of great prosperity, when the time of depression comes, Pittsburgh regains her supremacy.

## Natural Gas.

A paper on the industries of Pittsburgh and vicinity would be singularly deficient that made no mention of this remarkable fuel, which rises from nature's laboratory in this wonderful region, with a force or pressure of 150 to 250 pounds per square inch, and in quantity bewildering in its immensity.

The existence of this gas has been known for centuries, and it has been utilized in a small and desultory way in various parts of Western Pennsylvania for at least a half century.

The wells at New Cumberland, West Virginia, have supplied gas for more than twenty years for the manufacture of bricks. The East Liverpool wells have been burning for over twenty-five years and are still productive. At Leechburg and Apollo, the gas has been used in heating and puddling furnaces since 1872. At Beaver Falls, natural gas has been used since 1876 in the cutlery works; but

about two years ago the gas failed, presumably on account of the wells becoming obstructed by more or less solid matter.

The Butler county oil-field was the first in which the large productive wells of natural gas were struck. The writer visited the celebrated Delamater well in 1876, in company with some of the foreign judges of the Centennial Exposition, who were, as well may be imagined, perfectly overwhelmed with astonishment at the manifestation of energy displayed in the escape of the gas at enormous pressure. The mill of Spang, Chalfant & Co. has been supplied from this field since 1875. In 1877, the first well, known as the Haymaker well, was bored at Murraysville. It was visited by me in the spring of 1879, and I then advocated its purchase and the bringing of the gas to the Edgar Thomson Steel Works, of which I was the General Manager, but my advice was not acted upon. It was not until 1883 that this immense storehouse of potential energy was made useful by Pew & Emmerson, who laid a line of pipe from the Murraysville well to, and into, the city of Pittsburgh. In June, 1884, the celebrated Westinghouse well, located in the 21st ward of the city of Pittsburgh, struck the gas at a depth of about 1600 feet; and from that date the development of gas-wells in this vicinity has been enormous, and its adoption as a fuel by the manufacturing establishments of the city and county has been general. In an experiment made by the Committee on Natural Gas, appointed by the Engineers' Society of Western Pennsylvania (from whose report most of my data upon this subject are copied), it is reported that a boiler which evaporated 9 pounds of water to the pound of coal consumed, evaporated 20.31 pounds of water to the pound of gas consumed, and taking a pound of gas to be 23.5 cubic feet, this indicates a pound of gas to be equivalent to 2.255 pounds of coal, and a pound of coal to be equal in value as a combustible for evaporating water to 10.42 cubic feet of the gas. It was believed by the Committee that the boiler upon which the tests were made was not specially adapted to the development of economy in the consumption of gas, and it is probable that the relative value of the coal to the gas is more nearly one pound of coal equal to 7.5 cubic feet of gas. Experiments made by the Committee indicate the explosive point of the gas to be a mixture of *one* volume of gas to *ten* volumes of air; and as the quantity of air was either increased or decreased, the explosive character was reduced. The most economical mixture, so far as developed by the Committee, seemed to be that of *one* volume of gas to *eight*

volumes of air. The economical advantages of the gas are so many and so various that its value is much greater in proportion to coal than is indicated by its relative calorific value. Requiring no firing, leaving no ashes to be removed, containing little or no sulphur, being capable of mixture with pre-heated air, insuring thorough combustion; these are the most obvious advantages found in its use, and they are not offset, to any great degree, by the explosive character of the fuel.

Of the explosions which have taken place since its introduction into the city of Pittsburgh, all have been traceable either to a broken or leaky main, the gas from which found its way into adjacent cellars or other open spaces where it became mixed with air to the explosive point, or they have occurred from gross negligence on the part of the parties engaged in its use. So far as I am aware, not a single explosion has occurred on the premises of any dwelling-house where the gas was in use; and similar has been the experience in other cities and towns where the gas has been used for domestic purposes for from five to twenty years past. I can bear personal testimony to its value for domestic use, having had no other fuel or light in my house, in this city, for a year past; and the amount of comfort in its use, as compared with that of coal, is simply indescribable. Contrary to the opinion expressed by some of the members, when the report of the Committee was made, the gas has come into very general use in the manufacturing establishments of the city and county.

The steel and iron manufacturers, whom one of our valued members tried some years ago, but without success, to induce to adopt regenerative furnaces in the place of their wasteful coal-furnaces, have almost universally adopted gas furnaces (although most of them are not regenerative) since the natural gas has been brought into the city.

In the manufacture of glass, the gas is found to be a remarkable advantage both in the economy of cost and in the quality of the product. Especially is this the case in the manufacture of plate-glass as before intimated.

A partial report of the plant now in use, and the quantity of coal displaced by gas, by one of the companies now supplying the city, shows the following facts:

1st. The supply of gas is drawn from 42 wells, located in the Murraysville, Tarentum, and Washington fields, about 20 to 22 miles from the post-office, and in the 21st ward of the city, about 6 miles out.

2d. The mains and distribution pipes now laid consist of:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 24 inch, | | 52,557 feet | = | 9 | miles, | 5037 | feet |
| 20 | " | 67,009 | " = | 12 | " | 3649 | " |
| 16 | " | 29,103 | " = | 5 | " | 2703 | " |
| 12 | " | 58,728 | " = | 11 | " | 648 | " |
| 10 | " | 186,348 | " = | 35 | " | 1548 | " |
| 8 | " | 735,488 | " = | 139 | " | 1568 | " |
| 6 | " | 464,887 | " = | 88 | " | 247 | " |
| 4 | " and less, | 179,542 | " = | 34 | " | 22 | " |
| | Total, | 1,773,662 | " = | 335 | " | 4862 | " |

3d. The amount of coal displaced by this Company's gas is about 10,000 tons per day, and the domestic consumption has scarcely begun. The business of the Company is reported as still growing rapidly and constantly.

## Locomotives.

The two locomotive works referred to in my former paper are still in active and successful operation. The Pittsburgh Locomotive and Car Works, in Allegheny City, having a capacity of locomotives per annum, manufactures those of standard size as well as those of smaller type for narrow-gauge roads, while the light locomotive works of H. K. Porter & Co. continues to manufacture mine-engines, switching-engines, and others of light character.

## Bridge Works.

The Keystone Bridge Co., established in 1860, has materially increased its capacity since the date of my last paper. Its work in the St. Louis bridge will always be a monument to the skill of its managers both in construction and erection.

The Iron City Bridge Works of Mr. C. J. Schultz has also been increased in capacity since my former paper, while the Schiffler and the West Pennsylvania Bridge Works have been added to the list.

The manufactories of plows and other agricultural machinery and implements, bolts and nuts, spikes and rivets, cast-iron pipe, chain-cables, iron forgings, axes, saws and shovels, stoves, hardware, steam and gas-fitting materials, safes, axles, wagons, etc., are too numerous for special mention within the limits of this paper.

According to an estimate prepared by the Chamber of Commerce in 1884, the mining, mechanical, and manufacturing industries located in Allegheny County, and including those in contiguous

counties having their business headquarters in Pittsburgh, aggregated 3583 establishments, employing 101,261 men, with capital amounting to $132,478,000, and producing annually an output valued at $181,014,000.*

The production of Allegheny county has reached, during one or more of the seven years since our last meeting here, over one-eighth of all the pig-iron, over one-fifth of all the rolled iron, except rails, nearly one-half of all the pipe and tubing, nearly one-fifth of all the pneumatic and open-hearth steel, over two-thirds of all the crucible steel, over one-fourth of all the glass, one-fourteenth of all the bituminous coal, two-thirds of all the coke, and one-sixth of all the pig-lead produced in the United States.

Gentlemen of the Institute: The "State of Allegheny" has been heard from again, and not for the last time. I desire to record it here as my conviction, that if the Institute should hold meetings in this city septennially hereafter, before the time for the second septennial (which would occur in 1900), the manufacturing industries of Allegheny county will in the aggregate have doubled upon the record herein presented. May I be here to state, and you to hear, the glorious record upon that occasion!

## APPENDIX.

Summary estimate of the Mining, Manufacturing, and Mechanical industries of Pittsburgh, Allegheny City, and vicinity, showing number of employees, number of establishments, capital invested, and value of annual production, exclusive of professional and agricultural pursuits, and the railroad, river, and other transportation interests.

| Establishm'ts. | Class of Manufactures. | Employees. | Capital. | Product. |
|---|---|---|---|---|
| 5 | Agricultural Implements, | 525 | $475,000 | $800,000 |
| 2 | Artificial Limbs, | 20 | 20,000 | 20,000 |
| 5 | Awnings and Tents, | 25 | 20,000 | 20,000 |
| 1 | Axe Factory, | 250 | 150,000 | 310,000 |
| 4 | Axle Factory, | 60 | 67,000 | 112,000 |
| 146 | Bakers, | 480 | 560,000 | 870,000 |
| 2 | Barbed Wire Works, | 420 | 380,000 | 700,000 |
| 33 | Boat and Barge Builders, | 320 | 160,000 | 600,000 |

* See Appendix for list in detail.

| Establishm'ts. | Class of Manufactures. | Employees. | Capital. | Product. |
|---|---|---|---|---|
| 2 | Bell Foundries, | 40 | 30,000 | 27,000 |
| 4 | Bitters Manufacturers, | 120 | 180,000 | 330,000 |
| 16 | Blast Furnaces, | 2,430 | 5,240,000 | 10,800,000 |
| 2 | Block Makers, | 16 | 7,000 | 18,000 |
| 21 | Boiler and Tank Manufacturers, | 1,300 | 1,650,000 | 2,280,000 |
| 7 | Bolt and Nut Works, | 420 | 480,000 | 820,000 |
| 223 | Boot and Shoe Mkrs. and Mfrs., | 840 | 760,000 | 920,000 |
| 18 | Bottlers, | 120 | 180,000 | 320,000 |
| 6 | Box Factories, | 116 | 160,000 | 215,000 |
| 20 | Brass Foundries, | 330 | 570,000 | 840,000 |
| 21 | Breweries, | 310 | 1,680,000 | 1,830,000 |
| 28 | Brick Makers, | 420 | 390,000 | 420,000 |
| 5 | Bridge Works, | 940 | 920,000 | 1,950,000 |
| 3 | Britannia Ware, | 74 | 65,000 | 120,000 |
| 7 | Bronze Founders, | 80 | 160,000 | 180,000 |
| 5 | Broom Factories, | 105 | 51,000 | 102,000 |
| 9 | Brush Factories, | 95 | 90,000 | 160,000 |
| 380 | Butchers, | 740 | 570,000 | 2,360,000 |
| 106 | Carpenters, | 1,930 | 206,000 | 830,000 |
| 23 | Carriage Makers, | 160 | 140,000 | 230,000 |
| 4 | Chain Factories, | 300 | 80,000 | 330,000 |
| 4 | Chemical and Acid Works, | 600 | 1,360,000 | 1,410,000 |
| 270 | Cigar Factories, | 620 | 240,000 | 740,000 |
| 3 | Cigar Box Factories, | 60 | 23,000 | 41,000 |
| 276 | Clothing and Dressmaking, | 2,400 | 914,000 | 3,400,000 |
| 240 | Coal Works, | 18,000 | 16,240,000 | 12,000,000 |
| 9 | Coffee Roasters, | 130 | 300,000 | 1,100,000 |
| 15 | Confectioners, | 200 | 180,000 | 548,000 |
| 95 | Coke Works, | 6,000 | 12,150,000 | 6,000,000 |
| 30 | Contractors, | 460 | 160,000 | 320,000 |
| 42 | Cooperage Works, | 630 | 720,000 | 1,460,000 |
| 2 | Copper Works, | 160 | 600,000 | 975,000 |
| 4 | Coppersmiths, | 52 | 45,000 | 63,000 |
| 4 | Cordage and Twine, | 60 | 36,000 | 61,000 |
| 1 | Cork Manufacturers, | 220 | 385,000 | 475,000 |
| 2 | Cotton Mills, | 700 | 520,000 | 700,000 |
| 2 | Crucible Makers, | 45 | 210,000 | 224,000 |
| 7 | Distilleries, | 270 | 1,150,000 | 4,070,000 |
| 5 | Dry Docks, | 75 | 125,000 | 85,000 |
| 12 | Dyers, | 60 | 25,000 | 40,000 |
| 5 | Electric Light, | 212 | 300,000 | 280,000 |
| 3 | Electrotypers, | 12 | 7,000 | 9,000 |
| 32 | Engine Builders, | 1,860 | 3,140,000 | 4,230,000 |
| 22 | Fire Brick and Clay, | 680 | 590,000 | 860,000 |
| 4 | Flour Mills, | 90 | 380,000 | 1,320,000 |
| 5 | Forges, | 560 | 680,000 | 830,000 |
| 52 | Foundries, | 1,830 | 2,650,000 | 3,210,000 |
| 72 | Furniture and Chairs, | 670 | 510,000 | 1,180,000 |

| Establishm'ts. | Class of Manufactures. | Employees. | Capital. | Product. |
|---|---|---|---|---|
| 4 | Galvanizers, | 310 | 140,000 | 320,000 |
| 2 | Gas Machine Manufacturers, | 40 | 20,000 | 40,000 |
| 58 | Glass Manufacturers, | 6,650 | 6,470,000 | 7,500,000 |
| 15 | Glass Makers' Materials, | 220 | 155,000 | 170,000 |
| 2 | Glue Manufacturers, | 90 | 72,000 | 145,000 |
| 19 | Hardware Manufacturers, | 800 | 730,000 | 850,000 |
| 43 | Harness Manufacturers, | 220 | 260,000 | 550,000 |
| 5 | Heaters and Ranges, | 40 | 47,000 | 53,000 |
| 2 | Hinges and Butt Works, | 210 | 160,000 | 310,000 |
| 43 | Iron Rolling Mills, | 21,000 | 22,000,000 | 36,000,000 |
| 12 | Iron Pipe Fitters, etc., | 330 | 470,000 | 620,000 |
| 10 | Iron Roofs, Cornices, Railings, | 280 | 320,000 | 520,000 |
| 2 | Jewellers, | 25 | 62,000 | 78,000 |
| 8 | Lamp Chimney Factories, | 600 | 320,000 | 730,000 |
| 5 | Lard Oil Factories, | 25 | 78,000 | 182,000 |
| 51 | Laundries, | 740 | 93,000 | 163,000 |
| 3 | Lead Manufactories, | 130 | 380,000 | 360,000 |
| 2 | Linseed Oil Works, | 33 | 126,000 | 270,000 |
| 5 | Lithographers, | 30 | 40,000 | 70,000 |
| 13 | Locksmiths, | 30 | 15,000 | 25,000 |
| 1 | Lock Manufactory, | 220 | 110,000 | 210,000 |
| 2 | Locomotive Works, | 250 | 560,000 | 1,100,000 |
| 16 | Lubricating Manufacturers, | 90 | 130,000 | 355,000 |
| 12 | Machine Shops, | 360 | 920,000 | 1,150,000 |
| 2 | Malleable Iron Works, | 400 | 300,000 | 720,000 |
| 6 | Malsters, | 40 | 140,000 | 156,000 |
| 6 | Mantel and Grate Manufacturers, | 60 | 72,000 | 76,000 |
| 21 | Marble and Granite Works, | 330 | 110,000 | 280,000 |
| 69 | Newspapers, | 430 | 1,530,000 | 1,160,000 |
| 4 | Nickel Platers, | 26 | 15,000 | 25,000 |
| 121 | Oil Producers, | 310 | 440,000 | 1,100,000 |
| 137 | Painters, | 320 | 85,000 | 230,000 |
| 8 | Paper Bag and Box Factories, | 110 | 290,000 | 390,000 |
| 4 | Paper Manufacturers, | 220 | 630,000 | 840,000 |
| 11 | Patent Medicine Manufacturers, | 260 | 240,000 | 650,000 |
| 7 | Pattern and Model Makers, | 80 | 30,000 | 90,000 |
| 6 | Pickle and Baking Powder, | 360 | 280,000 | 490,000 |
| 39 | Planing Mills, | 475 | 370,000 | 970,000 |
| 87 | Plumbers and Gas Fitters, | 390 | 420,000 | 470,000 |
| 8 | Pork Packers, | 170 | 630,000 | 1,600,000 |
| 2 | Potteries, | 40 | 30,000 | 60,000 |
| 63 | Printing, | 480 | 280,000 | 560,000 |
| 9 | Railroad Supplies, | 1,360 | 1,720,000 | 3,420,000 |
| 19 | Refineries, | 400 | 360,000 | 720,000 |
| 4 | Roll Manufacturers, | 160 | 280,000 | 290,000 |
| 23 | Roofing Manufacturers, | 240 | 320,000 | 410,000 |

| Establishm'ts. | Class of Manufactures. | Employees. | Capital. | Product. |
|---|---|---|---|---|
| 6 | Salt and Bromine, | 90 | 190,000 | 210,000 |
| 30 | Sash and Door Factories, | 620 | 360,000 | 820,000 |
| 4 | Safe Manufactories, | 160 | 130,000 | 160,000 |
| 6 | Saw and Tool Manufactories, | 860 | 910,000 | 1,420,000 |
| 30 | Saw Mills, | 350 | 670,000 | 970,000 |
| 2 | Screw Manufactories, | 80 | 120,000 | 140,000 |
| 11 | Sewer Pipe works, | 60 | 40,000 | 70,000 |
| 2 | Shovel Manufactories, | 600 | 800,000 | 920,000 |
| 5 | Silver and Gold Platers, | 20 | 30,000 | 40,000 |
| 18 | Soap Manufactories, | 90 | 280,000 | 440,000 |
| 6 | Spike and Rivet works, | 350 | 650,000 | 1,840,000 |
| 4 | Springs, | 230 | 300,000 | 530,000 |
| 2 | Stained and Ornamental Glass, | 65 | 100,000 | 120,000 |
| 3 | Steam Pumps, | 60 | 85,000 | 120,000 |
| 2 | Steamboat Joiners, | 40 | 30,000 | 36,000 |
| 19 | Steel Works, | 8,100 | 12,000,000 | 18,300,000 |
| 4 | Stills and Tanks, | 40 | 25,000 | 54,000 |
| 12 | Stoves and Ranges, | 620 | 510,000 | 740,000 |
| 18 | Tanneries, | 460 | 1,230,000 | 3.400,000 |
| 15 | Tinners, | 230 | 330,000 | 840,000 |
| 3 | Tobacco, | 130 | 105,000 | 320,000 |
| 5 | Trunks and Valises, | 40 | 30,000 | 56,000 |
| 4 | Tube Works, | 1,600 | 1,975,000 | 5,400,000 |
| 25 | Upholsterers, | 80 | 74,000 | 160,000 |
| 4 | Varnish, | 25 | 16,000 | 56,000 |
| 4 | Vinegar, | 30 | 241,000 | 24,000 |
| 6 | Wagon Builders, | 270 | 260,000 | 420,000 |
| 5 | Wire Workers, | 45 | 65,000 | 78,000 |
| 2 | Woollen Mills, | 60 | 105,000 | 145,000 |
| 9 | White Lead Works, | 330 | 1,450,000 | 1.840,000 |
| 3583 | Totals, | 101,261 | $132,478,000 | $181,014,000 |

## *THE NOVA SCOTIA GOLD MINES.*

BY E. GILPIN, JR., A.M., F.G.S., F.R.S.C., ETC., INSPECTOR OF MINES FOR THE PROVINCE OF NOVA SCOTIA, HALIFAX, N. S.

THE Nova Scotian gold fields have yielded so little in comparison with those of the United States, that a lengthy description of them would almost appear unnecessary. However, not only are they interesting from a geological point of view, but experience has shown

that they present prizes to the miner, and that the extent of territory known to be auriferous is ample enough to warrant the expectation that their yield will be largely increased in the future.

The date of the first discovery of gold in Nova Scotia is unknown. Many years ago the sands of the Avon River, near Windsor, were washed by those living on its banks; but this work was not profitable, and was probably resorted to merely to fill up idle time. Curiously enough, nearly a century ago, importance was attached to certain lands in what is now the Waverley gold district, as they were stated to contain gold; but no attempts were made to find the source of the metal. Following the Californian excitement, diligent search was made in this Province for gold, but without success until 1858; and from that year may be dated the beginning of gold mining in Nova Scotia.

Discoveries were then announced from many points between Canso and Yarmouth, and from numerous localities quite outside the auriferous ground. There was much excitement; large amounts of capital, domestic and foreign, were invested, and the inevitable crowd of practical miners and of speculators crushed both quartz and capital. The mills were usually defective in pattern and construction, and the mining was improperly conducted. In a few years the companies, for the most part, disappeared, and the tributor had his day. However, with a better appreciation of the extent and character of the veins, this has been changed; we now find companies with comparatively small capital doing well with economical mining and milling; and these, with a few individuals working on tribute, make up our annual production.

The Nova Scotia gold-field stretches irregularly along the Atlantic shore from Canso to Yarmouth, but no exact estimate can be given of its extent. Various authorities estimate it at from 6,000 to 7000 square miles, of which about one-half may be occupied by irregular bands of granite rock. The Geological Survey has mapped out part of the eastern end, but some years must necessarily be spent before it can give us much information. The country underlain by these two rock-series is in many places unfit for cultivation, and is valued chiefly for lumbering purposes. Along the river valleys, however, and in Lunenburg and Yarmouth counties, there are good farming-lands. The strike of the measures being parallel to that of the coast, the shore is fringed with innumerable islands. The erosion being transverse to the strike, the coast is indented by numerous bold and deep harbors and bays. These con-

ditions unite in presenting a wild and charming coast-scenery, and a pleasant resort for the tourist and sportsman.

## Age of the Gold-Bearing Rocks.

It is not yet definitely settled what is the age of these measures. The following is Sir William Dawson's general comparative table, taken from the supplement to his *Acadian Geology*.

*Cambrian.*

| England, etc. | Nova Scotia and New Brunswick. |
|---|---|
| Tremadoc slates and Lingula flags. | Miré and St. Andrew's series in Cape Breton. |
| Menevian series. | Acadian series, St. John, N. B. |
| Longmynd series, Harlech grits and Llanberis slates. | Quartzites and slates of the Atlantic coast of Nova Scotia. |

The Acadian series of St. John forms the equivalent of the series known in England as the Menevian, or Barrand's Etage C, of the Primordial in Bohemia. The Atlantic coast series, with its two divisions of quartzites and clay slates, so divided from the respective predominance in each of the rocks named, are considered by Sir W. Dawson, Dr. Selwyn, and Professor Hynd to precede them.

Hitherto, fossil evidence has thrown little light upon the subject. Dr. Selwyn has recognized in the Lunenburg slate markings of the nature of those named in Sweden *Eophyton*. Dr. Dawson, however, considers them the markings of aquatic animals named by him *Rhabdichnites*, which are characteristic of the Acadian series. Professor Hynd discovered at Waverley nodular bodies and markings, which Mr. Billings referred with doubt to the genus *Eospongia*, and casts of *Orthis*. Dr. Dawson states that they may be compared with the problematical object from the Eophyton sandstone of Sweden, described by Linnarson under the name *Astylospongia radiata*, but considers them fucoids with radiating fronds, allied in form to Hall's *Phytopsis* from the Birdseye limestone, or to Linnarson's *Scotolithus* from the *Eophyton* sandstone, and has given them the name of *Astropolithon*. The only other fossil forms observed are tubes from St. Mary's River, resembling *Scolithus*.

So far as this evidence is available it serves to confirm the opinion that the measures in question are to be referred to the Cambrian period. Within that period, the fossils may be compared with those

of the *Eophyton* or fucoidal sandstone of Sweden, which underlies the equivalent of our Acadian series.

They may, therefore, be regarded as probable equivalents of the Lower Cambrian or Longmynd series of Europe.

## The "Granites."

The "granite" rocks of Nova Scotia stretch irregularly through the gold-measures. One great band running from Halifax nearly to Windsor, stretches to Yarmouth, interrupted by irregular belts of auriferous measures. To the eastward of Halifax, another interrupted belt extends from Waverly to the Cape of Canso. These rocks are little known, and have never been mapped. The outlines given in the accompanying map are from *Acadian Geology*, the writer's notes, etc.

So far as any attention has been paid to these rocks, the opinion of Sir W. Dawson that they are intrusive masses is confirmed. Near Sherbrooke, the quartzites are slightly altered at the point of junction with the granite, having apparently minute hornblende and mica crystals developed in them; but the granite sends numerous veins into the quartzite, and in these veins becomes coarser in texture, and presents aggregations of plumose mica. At Cochran's Hill auriferous measures lie close to one of the granite bands, and are penetrated by veins of granite from one inch to six feet in thickness. The measures show a metamorphism equal to that found anywhere in the coast series. The slates have become perfectly crystalline. Mica schists, or micaceous gneisses, with crystals of chiastolite and staurolite, have been developed in them.

Sir W. Dawson similarly describes the granites of Nictaux, as altering the Devonian beds and converting them, for a short distance away from the junction, into gneissoid rocks, holding garnets. The granite sends veins into the strata, and near the junction holds numerous angular fragments of altered slate. In the case of both the auriferous and Devonian strata, the gradual passage from gneissoid rock into the normally metamorphosed quartzite and slate can readily be observed.

The Nova Scotia granite has all the characters of a plutonic rock in its want of stratification, its frequent porphyritic appearance, its passage into graphic granite, etc., and closely resembles in lithological characters the intrusive granites of the eastern townships of Quebec and New England, some of which belong to the Montalban series of Hunt, while others are later than the Upper Silurian; and it

differs materially from the typical Laurentian of Canada. In the latter the gneisses are usually hornblendic, laminated, and interstratified with diorites, pyroxene rock, limestone, serpentine, etc.

The granites are evidently older than the Carboniferous, for at Horton their detritus is found in the Lower Carboniferous. At Nictaux they penetrate rocks of Oriskany age. They are therefore much more recent than the auriferous strata, to which a much greater age must be assigned.

The pre-Carboniferous date of the gold veins is referred to later in this paper. From the relation which appears from the map to exist between the granites and the gold districts, it may be inferred that since the veins, as at Cochran's Hill and elsewhere, cut the granite bands, the granite intrusions and the formation of the veins are, as Sir W. Dawson expresses it, "roughly contemporaneous."

## The Gold-Bearing Rocks.

So far, two divisions of the auriferous measures have been recognized. The upper one is composed largely of dark pyritous slates, with beds of quartzite, and carries veins of quartz, usually small and irregular, but often showing gold. The lower division presents alternations of compact quartzites and sandstones, locally known as "whin," frequently felspathic, but rarely calcareous, with argillaceous slates, in some cases magnesian or chloritic, and includes numerous quartz veins.

No exact estimate has yet been made of the thickness of these two divisions. Professor Hynd has estimated the thickness of the upper at 3000 feet; but at several points the writer would be inclined to allow much larger figures. The thickness of the lower divison has been estimated at 9000 feet. The lower division only has hitherto yielded workable veins. These veins appear to be confined to no particular horizon; but it would appear in some localities that, toward the top of the lower division, quartzites predominate, and the veins become less numerous and poorer in their gold contents. At Waverley, gold-bearing veins are known through a thickness of 3500 feet, while the thickness of the gold belt worked at Renfrew is 5000 feet.

This great mass of sediment has been folded in undulations having an east and west course. The regularity of these folds may be gathered from the fact that the general course of the shore east of Halifax is about east (magnetic), while the axes of the best known synclinals run as follows:

| | |
|---|---|
| Sherbrooke, | E. and W. |
| Fifteen Mile Stream, | S. 80° E. |
| Beaver Dam, | S. 57° E. |
| Tangier, | E. and W. |
| Carribou Moose River, | N. 87° E. |
| Carribou Jennings, | N. 74° E. |
| Chezetcook, | N. 75° E. |
| Lawrencetown, | S. 87° E. |
| Waverley, | N. 81° E. |
| Oldham, | N. 82° E. |

These undulations have been followed by transverse subordinate north and south folds. The number of these main folds and their relation to each other are obscure; but ten of them have been recognized on a line of section running north and south through Halifax. The folding of this immense mass of sediments has, in some cases, been so great as to cause overturn dips, and vertical dips extending for long distances on each side of the axial line. Denudation and erosion have been equally powerful, so that the crests of these folds have, in many cases, disappeared, leaving a central anticlinal exposure of the measures of the lower division, frequently over two miles in width, with the black slates of the upper division surrounding it.

These denuded crests now form our gold districts, and the irregular folding explains the apparently capricious distribution of the auriferous localities as marked on the map. In these upturned divisions of the lower measures occur the veins hitherto worked. At first sight they appear to be true beds of quartz, for they run parallel to the strata, and follow its turns at the apices of the foldings.

The following condensed section of the measures and veins of the Waverley gold-fields, is from a report made on that district to the Provincial government some years ago, by Professor Hynd:

The measures were originally thrown into an immense fold, the base, or east end, of which rests on the granite, while the westerly prolongation can be traced several miles. Subsequent faults have shifted the axis of the anticlinal and brought up lower beds.

The lowest bed met in the Waverley district is a thin bed of greenish and gray slate. The following is a general section in ascending order:

1. *Barrel Quartz Group.*—Comprising 120 feet of quartzite, with slate belts, and holding four veins.

2. *Rose Group.*—Comprising 60 feet of quartzite, with greenish-gray and bluish slates, highly pyritous, and holding three veins.

3. *Taylor Group.*—This group is marked by a bed of concretionary quartzite, already referred to as being fossiliferous, and 70 feet thick; and by thin beds of plumbaginous slates, with metallic luster. It has a total thickness of 320 feet, and contains 27 veins, the thickest averaging 18 inches.

4. *Tudor Group.*—Thickness 190 feet, holding three veins. It is characterized by two beds of massive gray quartzite holding large crystals and nodules of mispickel and pebbles of slate.

5. *South Group.*—This group is 600 feet thick, and holds numerous veins not yet worked to any extent.

However much, at any given point, these quartz deposits resemble beds, a closer study would rather show that they are, in the strict sense of the word, veins. They are found, sometimes to pinch out, and the fracture to continue; to pass, in some cases abruptly, from one stratum to another; to show banded structure; to throw out "feeders;" to hold inclusions of the slates, horses, etc.,—all so markedly, that miners claim them at once as veins.

The readiest way of accounting for these fissures would apparently be to suppose that the measures, consolidated and probably metamorphosed, opened along the planes of contact of beds of differing rigidity and softness, as they were being lifted and relieved from pressure during folding. This would explain some of the more puzzling forms of veins observed here. Thus, at the apices of several of the districts, where the denudation has left the measures unbroken, and where, during the period of plication, the pressure would be greatest, the measures are highly corrugated in small rolls, and the quartz vein in section resembles small tree-trunks laid side by side. These openings were, probably, in many cases increased and altered by water, and the filling of quartz may be assumed to have accompanied or to have closely followed their formation.

The accumulation of auriferous quartz veins at this horizon did not end here. The transverse foldings were, in many cases, accompanied by faults; and, when circumstances permitted, these were filled with quartz veins in many cases auriferous. The courses of these cross-veins are frequently irregular. They twist in every direction, and lie at every angle with the horizon and the strike of the bedded veins. Other secondary veins are also observed, which run with the measures, and, in some cases, impinge upon and change the regular veins. I believe that they are seldom auriferous, except where they touch veins showing gold. They vary in size up to 12

feet, are sometimes continuous for long distances, and are generally composed of hard milky quartz, carrying but a trace of any metal. Other faults, not carrying quartz, are believed to be of comparatively recent date, and are frequently troublesome to the miner by allowing the passage of surface-water into the workings. I am aware of only one "dike" cutting the gold-measures, although doubtless others have been observed. This one occurs at Tangier, is about forty feet wide, and runs nearly north and south without materially affecting the strata and veins. It is said not to show gold. Similar bedded dioritic dikes are said to occur in the Lunenburg slates, presumably belonging to the upper division.

There appears to be no rule governing the relation of the value of the veins to the nature of the encasing rocks. Generally speaking, the miners consider that veins are poorer in wide bands of slate, or in quartzites, than when they occur in measures composed of alternations of slate and quartzite.

The thickness of the veins at present worked varies from two inches to six feet. The usual width is from four to eight inches, and a twenty-inch vein is considered a large one. Their horizontal extension varies from a few hundred feet to over two miles. The minerals usually associated with the gold are sulphides and arsenides of iron, galena, blende, copper pyrites, oxide of iron, copper glance, molybdenite, native copper, sulphur, chlorite, feldspar, mica, garnet, calcite, felsite, etc.; not in quantities of economic importance. The presence of mineral matter appears essential to the value of the vein. In some veins, sulphide and arsenide of iron are usually the most intimately connected with the gold. At the New Albion mine, at Montagu, the chief vein is, as the miners say, "nuggety," and the presence of galena and copper pyrites is considered an infallible sign that they are approaching some rich ground.

The gold occurs in the veins under no fixed rule—in one vein on the wall-side, in another along the center-line, or following an irregular course of mineral. It is usually met as free or coarse gold in grains visible to the naked eye, but some is hid in minute strings or filaments in the associated minerals. The miners never crush quartz not showing gold; and I have not seen any record of valuable quartz here, which did not give "sights." Crystals are sometimes observed, and they are apparently pseudomorphs after the minerals they have replaced.

## Pay-streaks.

The distribution of the gold in the veins is in the form of belts or pay-streaks.* We are still ignorant of the rules governing their position and extent in our veins. Nearly all veins that have been worked, have shown one or more of these pay-streaks. Their form is extremely irregular, and their pitch equally uncertain; their horizontal dimensions vary from 50 to 300 feet, and they have been followed to a depth of about 600 feet. The pay-streaks of any district usually pitch in the same general easterly or westerly direction. Varying amounts of folding and erosion now present them in every stage, some being nearly all swept away, while the apex of others has been accidentally discovered by prospecting levels.

No attempts have yet been made at the lower end of a pay-streak, either to search for its possible renewal at a deeper level, or, in the case of a district in which the pay-streaks lie at a light angle, to deepen a shaft in the hope of striking a lower and parallel one. Quartz from a pay-streak will sometimes run as high as 40 ounces to the ton, while the regular vein-rock may vary from 5 pennyweights to an ounce, to the ton. There are, of course, veins which have not yet shown well-defined pay-streaks, and from which considerable amounts of quartz have not shown a yield exceeding one-half to three-quarters of an ounce.

## Low-Grade Ores.

In several districts, zones, up to 1000 feet in width, have been observed, running transversely to the general strike of the veins, in which the veins appear to present no change from their normal gold values, but the slates are decidedly auriferous, the quartzites remaining valueless. The beds of slate in these zones frequently carry numerous small irregular veinlets of quartz, sometimes showing gold abundantly. This ground is frequently worth crushing, the mill-tests showing from 3 to 7 pennyweights to the ton. At Mount Uniacke and Sherbrooke, large belts of this ore have been several times worked on a small scale. The workings, so far as they have been carried, are open, the whole face being quarried, and the rock roughly sorted at bank. The quartzite is rejected, except when it

* Called in the Western United States "ore-shoots" or "chimneys."

is enriched by feeders and stringers of quartz. I think, that, in the future, this branch of gold-mining will prove important in these gold-fields, if the ore be systematically quarried, and crushed in mills of proper dimensions. Hitherto, it has been treated in small mills adapted to the hard vein-quartz, and disadvantageously located. Rolls might prove cheaper than stamps for much of this ore; and, in all cases, the disposition of the appliances and the saving of hand-labor must be carefully studied.

## Alluvial Gold.

In Nova Scotia, contrary to the history of most gold-mining countries, alluvial work has played an insignificant part. It is generally believed that the gold, loosened by the causes which have contributed to the present contour of the country, has all been swept away into the Atlantic. This is a mistake. Australian miners assert that bare rock-surfaces are not more abundant in the district under consideration than in the gold districts of Australia. Small amounts of gold have been procured by alluvial work at Tangier, Waverley, and Moose River, but no systematic attempts have been made to test the old river-channels, or the still waters, etc., of the present drainage systems, which run transversely to the strike of the veins. Many of the districts have a surface apparently rich enough to treat by sluicing and crushing, and several of the rivers are reported to give good tests.

In most of the gold districts, the presence of valuable veins is indicated by surface boulders of auriferous quartz, and the labor of the prospector is frequently lessened by following them to the north along the line of the striation of the rocks. The boulders are carried various distances up to 1800 feet, and, in some instances, the striæ on the underlying rocks pointed like arrows to the portion of the vein which yielded them to nature's great plough. Some years ago, in a paper read before the North of England Institute of Mining Engineers, I drew attention to this local transportation, and to its presence, side by side, with a more extensive system. At numerous localities through the auriferous district of the Province, are met hills and mounds having a general north and south course, and made up of clay mixed with gravel and boulders of every size and degree of attrition. Many of the boulders can be traced to their source in the granitic ranges, often several miles distant, and the fragments of Carboniferous and of later traps, and of sandstones, resembling none

now known here in measures older than the Carboniferous, must have been carried over a far greater interval. These hills have been observed, surrounded by and merging into the districts already alluded to as distinguished by auriferous veins, and by a *detritus* carried but a short distance.

If the reason for this varying cover is to be sought for in a single cause, there may first have been in the district under consideration, conditions permitting the deposition of material derived from distant sources, then with a rise of land the impact of ice would give striation and limited transportation; or else a more or less general covering derived from distant sources has, through a change of level, been subjected to a force gouging through it, and scattering fragments and masses of quartz along the line of its impact.

There are two curious instances of alluvial gold in the Province. At Lunenburg, on the Atlantic coast, an auriferous alluvium can be seen in the process of formation. Here an immense mass of dark pyritous slates (probably belonging to the upper division) carries numerous small and irregular veins, frequently auriferous, and lies exposed to the waves of the Atlantic. Their rude assaults have worn away great masses of the yielding slates, and have concentrated on the beach considerable amounts of gold. In the early days of gold-mining these sands were rudely washed, and profitable returns were made; but the extent of workable ground being limited, they have ceased to attract attention, although each storm enriches the beach again.

At Gay's River, near Shubenacadie, there rests on the auriferous measures a bed of indurated conglomerate, overlaid with coarse grits, etc. This has been considered by geologists to represent the basal conglomerate of the Carboniferous series, but it may really be a comparatively recent river-bed. The upturned edges of the slates are intersected by small seams, frequently carrying gold in clay and iron rust, and the sand resting on the slates and the lower part of the conglomerate is auriferous. Some years ago, considerable quantities of this conglomerate were taken out and profitably crushed in a little mill. None of the ground was very rich. It averaged from 2½ to 5 dwts., but was cheaply mined. As these operations proved a considerable extent of auriferous ground, an attempt is being made to test it on a large scale.

## Mining.

The veins dip at all angles, and are invariably opened by shafts sunk on the dip of the vein. Text-books lay down other rules, but this system appears to be the proper one here. The dip of the veins is seldom irregular enough to cause any difficulty in arranging the skip-road; and frequently the bedding-planes of the encasing rocks are found to make two excellent walls to the shafts, and in many cases the quartz extracted in sinking has materially reduced the cost of the shaft. These shafts are from 80 to 200 feet apart. At any selected depth, seldom exceeding 100 feet, stopes are carried directly from the shaft, which is protected by blocks of the vein, or by closely packed scaffolds of heavy timber. The work is done by underhand stoping, with two men to each drill, powder or dynamite being the explosive, according to the hardness of the rock. These stopes are opened through to each shaft, and the ore is hoisted through the most convenient one by means of friction-gear from an engine placed at a central point.

At first it was customary to take at one operation the vein, and, if required, enough of the wall-rock to give room for the miners to work; but by this process, in the small rich veins, much of the ore was lost, and it was exposed to the cupidity of the miners. Now, in small veins, enough ground is first taken out beside the vein to allow working-room, and when a few hundred square feet have been exposed, it is taken down at one operation and passed directly to the mill. The walls are almost invariably strong, and easily held in place. This firmness and the tightness of the measures materially reduces the expense of pumping; and whenever the surface can be drained, little water finds its way into the workings. Few shafts have exceeded two hundred feet, the deepest being six hundred feet, at Sherbrooke. The cost of mining, there being little dead work, varies according to the size of the vein and the hardness of the encasing rock, from 50 cents a ton in the open-cast work to $15 a ton in the narrow and tight-bound veins.

## Milling.

The milling of these ores presents few features interesting to the miner in the United States. The mills are generally built in the Province, and compare favorably with those imported. The stamps

weigh from 600 to 750 pounds, and are run at a speed of from 30 to 50 drops a minute, crushing to each stamp, daily, about one ton of hard quartz, or one ton and a half of quartz and slate, to a fine mesh. Few mills hold over fifteen stamps, usually arranged in sets of five. Amalgamation in the batteries without plates is the rule. The tailings are passed over copper plates, and in a few cases attempts have been made to take out the sulphides, etc.

There have been several attempts at reworking old tailings by Frue and Embrey vanners, but so far, I understand, without success. The average value of the sulphides varies very much, but $25 would, perhaps, represent a general average. The amount of the metallic accessories in the veins varies from a trace up to 50 per cent., the latter only in very small veins, so that the total available metallic residue is small, and it is largely composed of arsenical pyrites and zinc blende. The most remunerative method of treating the tailings would probably be a rough concentration on a Frue vanner as they pass from the plates. It is questionable if they would repay any more expensive and systematic process.

## Tenure of Gold Lands.

All the gold in the Province is the property of the government, and it issues leases for three terms of twenty years. The areas are laid off in rectangular form, each area being 150 by 250 feet, with the shorter sides parallel to the general run of the veins and beds of the district. As shown by the table already given, this is practically an east and west course. The areas are bounded by vertical planes through the boundary-lines, and no provision is made for following the extension of the veins outside these limits. The fee paid for each area is two dollars. Similar areas can be taken under prospecting licenses for the space of six months on payment of a small registration fee. Provision is made whereby the holder of any lease can acquire, by arbitration or by grant from the government, the ground necessary for mining purposes. In return for this easy acquisition of the scene of his future bonanza, he is required, under risk of forfeiture, to employ every year, forty days labor on each of his leased areas; but enough may be done on two or three areas to hold all comprised in his lease. He is also required to make periodic returns of this labor, and of all lots of quartz mined or sent to any crushing mill.

Any party desiring to erect a mill must procure a license therefor, and give bonds for the proper discharge of his obligations, which are, to keep an account of all amounts of quartz crushed, and of the

names of the parties, and of the numbers of the areas furnishing them; and to pay to the government royalty on the gold extracted by his mill. This royalty is at the rate of 2 per cent. on smelted gold valued at $19 per ounce troy, and at the same rate on unsmelted gold which is valued at $18 per ounce. The average fineness of Nova Scotia gold is high, and is put by some authorities at 950 thousandths. By this arrangement the miner, having delivered his quartz to the mill-owner, becomes free from any responsibility about the royalty, as the government then looks to the licensed mill owner for it.

From the foregoing remarks it may be gathered that the extent of proved auriferous ground in this Province is very large, and that in its wide wooded tracts, seldom visited except by the hunter and lumberman, there is every probability of many more auriferous localities being discovered. In nearly every district hitherto worked, several veins have yielded handsome returns over and above the expenditure of mining and milling. The fact is now recognized that the small rich veins of this Province are not proper subjects for fancy prices on the part of the discoverers, or for high stock values; but that they afford a promising and safe investment for capital in amounts proportionate to their extent and gold contents. Numerous small companies and syndicates have made good returns by careful mining and milling on comparatively poor veins, when any approach to extravagance, or even to the customary expenditures of large companies, with big staffs and corresponding outlays, would have shown a loss.

The future, however, of gold-mining in Nova Scotia is based, I think, as much on the low-grade ores as on the small and rich veins which have hitherto almost exclusively made up the returns. The large number of districts in which tests have shown paying low-grade ores is a guaranty of the extent of such ground. The accessibility of all the districts, the low price of labor ($1 to $1.50 per day), the abundance of water-power, and a favoring climate, all tend to facilitate this branch of gold mining. As yet, no attempts have been made to work these ores, and it is readily understood how the Provincial miner, with his limited capital, and need of quick returns, should prefer the lottery of the readily-opened, small, rich veins to the heavier outlays and the regular work of the slate belts.

The following tables will serve to show the annual production of gold, and the amount furnished last year by the different mining localities.

## GOLD.—GENERAL ANNUAL SUMMARY.

| Year. | Total ounces of Gold extracted. | | | Stuff Crushed. | Yield per Ton of 2,000 lbs. | | | Total Days' Labor. | Average yield per man per day and year at 300 working days, $18 per oz. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Oz. | Dwt. | Gr. | Tons. | Oz. | Dwt. | Gr. | | A day. | A year. |
| 1862 | 7,275 | | | 6,473 | 1 | 2 | 11 | 156,000 | $ 83 | $249 |
| 1863 | 14,001 | 14 | 17 | 17,002 | | 16 | 11 | 273,264 | 92 | 276 |
| 1864 | 20,022 | 18 | 13 | 21,434 | | 18 | 16 | 252,720 | 1 42 | 426 |
| 1865 | 25,454 | 4 | 8 | 24,423 | 1 | 0 | 20 | 212,966 | 2 15 | 645 |
| 1866 | 25,204 | 13 | 2 | 32,161 | | 15 | 2 | 211,796 | 2 14 | 642 |
| 1867 | 27,314 | 11 | 11 | 31,386 | | 17 | 9 | 218,894 | 2 24 | 672 |
| 1868 | 20,541 | 6 | 10 | 32,262 | | 12 | 17 | 241,462 | 1 53 | 459 |
| 1869 | 17,868 | 0 | 19 | 35,147 | | 10 | 4 | 210,938 | 1 50 | 456 |
| 1870 | 19,866 | 5 | 5 | 30,829 | | 12 | 21 | 173,680 | 2 05 | 615 |
| 1871 | 19,227 | 7 | 4 | 30,791 | | 12 | 11 | 162,992 | 2 12 | 636 |
| 1872 | 13,094 | 17 | 6 | 17,093 | | 15 | 7 | 112,476 | 2 09 | 627 |
| 1873 | 11,852 | 7 | 19 | 17,708 | | 13 | 9 | 93,570 | 2 28 | 684 |
| 1874 | 9,140 | 13 | 9 | 13,844 | | 13 | 5 | 77,246 | 2 12 | 636 |
| 1875 | 11,208 | 14 | 19 | 14,810 | | 15 | 4 | 91,698 | 2 20 | 660 |
| 1876 | 12,038 | 13 | 18 | 15,490 | | 15 | 13 | 111,304 | 1 94 | 582 |
| 1877 | 16,882 | 6 | 1 | 17,369 | | 19 | 10 | 123,565 | 2 46 | 738 |
| 1878 | 12,577 | 1 | 22 | 17,990 | | 13 | 23 | 110,422 | 2 05 | 615 |
| 1879 | 13,801 | 8 | 10 | 15,936 | | 17 | 8 | 92,002 | 2 34 | 702 |
| 1880 | 13,234 | 0 | 4 | 14,037 | | 18 | 20 | 103,826 | 2 18 | 654 |
| 1881 | 10,756 | 13 | 2 | 15,556 | | 12 | 20 | 126,308 | 1 52 | 456 |
| 1882 | 14,107 | 3 | 20 | 22,081 | | 12 | 18 | 106,884 | 2 37 | 711 |
| 1883 | 15,446 | 9 | 23 | 25,954 | | 10 | 21 | 97,733 | 2 84 | 862 |
| 1884 | 16,079 | 14 | 10 | 25,186 | | 12 | 18 | 118,087 | 2 40 | 720 |
| 1885 | 21,600 | 0 | 0 | 29,000 | ..... | | | 156,361 | ..... | ..... |
| Total | 388,596 | 6 | 12 | 523,962 | ..... | | | 3,637,194 | ..... | ..... |

The figures for 1885 are close estimates, but not full returns. Assuming them to be correct, the average yield of the quartz crushed in 1885 would be 14 dwt. 21 gr. per ton of 2000 lbs., and the average of all quartz crushed since 1861, 14 dwt. 20 gr. The average yield per man per day and year, calculated as above, would be, for 1885, per day, $2.49; per year, $747; and the similar average for the whole period covered by the table, per day, $1.92; per year, $576. These figures indicate a considerable saving of labor, and, therefore, presumably an increase of profit, in mining and reducing quartz of average grade.

SKETCH MAP

SCOTIA GOLD FIELDS

CARBONIFEROUS

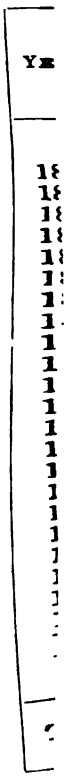
DEVONIAN

SILURIAN

CAMBRIAN

GRANITIC ROCKS

GOLD MINES



As
in
age
yie
18
the
Th
pr
av

## GOLD.—GENERAL STATEMENT FOR THE YEAR 1884.

*Showing the number of Mines, Days' Labor performed, quantities of Quartz crushed, yield of Gold, etc., for the year ended December 31st, 1884.*

| DISTRICTS. | Number of Mines. | Days' Labor. | Mills Employed. | Steam Power. | Water Power. | Tons of Quartz, etc. Crushed. | Yield per Ton. | | | Maximum Yield per Ton. | | | Total Yield of Gold. | | | Average yield per man per day for twelve months at $18.00 per ounce. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Oz. | Dwt. | Gr. | Oz. | Dwt. | Gr. | Oz. | Dwt. | Gr. | | |
| Caribou, | 3 | 7499 | 2 | 1 | 1 | 1559 | 0 | 12 | 9 | 2 | 10 | 0 | 966 | 19 | 22 | 2 | 32 |
| Darr's Hill, | 1 | 24935 | 1 | — | 1 | 9799 | 0 | 6 | 20 | 0 | 9 | 14 | 3397 | 0 | 0 | 2 | 45 |
| Fifteen Mile Stream, | 1 | 1573 | 1 | — | 1 | 107 | 0 | 16 | 13 | 1 | 5 | 21 | 88 | 14 | 3 | 1 | 00 |
| Montagu, | 2 | 4469 | 2 | 2 | — | 539 | 1 | 7 | 8 | 4 | 6 | 0 | 736 | 12 | 23 | 2 | 90 |
| Oldham, | 2 | 3011 | 2 | 1 | 1 | 921 | 0 | 17 | 21 | 2 | 3 | 12 | 824 | 15 | 12 | 4 | 80 |
| Renfrew, | 1 | 3170 | 1 | — | 1 | 1679 | 0 | 6 | 18 | 1 | 0 | 0 | 569 | 18 | 0 | 3 | 20 |
| Sherbrooke, | 8 | 22142 | 2 | 1 | 1 | 3268 | 0 | 16 | 7 | 6 | 14 | 12 | 2668 | 11 | 0 | 2 | 10 |
| Stormont, | 1 | 7337 | 1 | 1 | — | 913 | 2 | 8 | 10 | 3 | 17 | 5 | 2212 | 8 | 1 | 5 | 40 |
| Tangier, | 1 | 13589 | 2 | 2 | — | 1330 | 0 | 14 | 0 | 0 | 18 | 18 | 924 | 2 | 19 | 1 | 10 |
| Uniacke, | 2 | 4898 | 4 | 3 | 1 | 2235 | 0 | 10 | 4 | 1 | 4 | 5 | 1140 | 6 | 2 | 4 | 20 |
| Waverly, | 1 | 344 | 2 | 1 | 1 | 10 | 1 | 7 | 0 | 1 | 7 | 0 | 1 | 7 | 0 | — | — |
| Unproclaimed, etc., | 4 | 25120 | 7 | 3 | 4 | 2826 | 0 | 18 | 0 | 5 | 0 | 0 | 2548 | 19 | 0 | 1 | 80 |
| Total, | 27 | 118087 | 27 | 15 | 12 | 25186 | 0 | 12 | 18 | 6 | 14 | 12 | 16079 | 14 | 10 | 2 | 40 |

## *THE MINERAL RESOURCES OF THE HUDSON'S BAY TERRITORIES.*

BY ROBERT BELL, B.A.SC., M.D., LL.D., ASSISTANT DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA, OTTAWA, CANADA.

THE regions to which this paper refers include the whole of the Dominion of Canada east of the Rocky Mountains and north of the water-shed of the St. Lawrence. Very little exploration for economic minerals has yet been done in this immense country; but that little has already served to indicate great wealth in some localities. Having been engaged for a number of years in conducting government geological explorations in these vast territories, I shall endeavor to give the members of the Institute an idea of the prospective mineral resources of almost half a continent, as far as they are yet discernible. I purpose confining my observations to the economic minerals, and will not attempt a description of the geology of these territories; but it will be necessary to say a few words about the rocks in order the better to explain the distribution of such minerals.

The Laurentian nucleus of the continent is the principal feature of the geological map of the Dominion. It stretches from Lake Superior to Baffin's Bay, and from Great Bear Lake to the Straits of Belle Isle. Hudson's Bay itself, which is half the size of the Mediterranean Sea of the old world, lies in the center of this area. Its shores are bordered in places with newer rocks. On the west side of James' Bay (its southern prolongation) these extend inland over 200 miles, and consist of fossiliferous Devonian and Silurian strata. On the western and northwestern side of Hudson's Bay proper, altered rocks are met with, some of which resemble the gold-bearing strata of Nova Scotia, some the Huronian of Lake Huron, some the older Huronian, and others the crystalline series of the neighborhood of Sherbrooke in the Province of Quebec.

Along the east coast (called the Eastmain) and among the islands lying off it, there is an interesting set of volcanic and sedimentary rocks which appears to be identical with the Animikie and the Nipigon series of Lake Superior.

The area which I have characterized in a general way as Laurentian, includes tracts and belts, more or less extensive, of the Huronian series. Such areas appear to be most common, and have been best explored, in the country between the Great Lakes and Hudson's Bay.

Most of the islands of the Arctic Sea consist of Silurian strata. On some of the northwestern of them, Carboniferous rocks are supposed to be developed; but possibly, on further examination, these may prove to be Devonian and Cretaceous. Still further north, strata supposed to be of Liassic age have been found.

Between the Laurentian nucleus and the Rocky Mountains, there is a great basin of Silurian, Devonian, Cretaceous, and Tertiary rocks, which, towards the Arctic Ocean, becomes, to a great extent, replaced by non-fossiliferous limestone, probably of Nipigon age. On the shores of the Arctic Ocean, similar limestones, associated with trap, are the prevailing rocks between the Mackenzie and Coppermine rivers. The copper-bearing rocks of the latter river appear to correspond with those of Lake Superior.

In the following brief account of the economic minerals, I shall begin with the metallic ores.

*Iron.*—A fine variety of magnetite, of which I procured specimens, is said to occur in large quantities near the entrance of Black Bay, on the north side of Athabasca Lake. On Knee Lake, between Lake Winnipeg and Hudson's Bay, I have examined a large deposit of a laminated finely-granular magnetite which, however, Mr. Hoffmann finds to contain only 45.86 per cent. of metallic iron; but it is perfectly free from titanic acid. Magnetic iron-ore is reported to occur on the north side of Hudson's Strait; and small deposits of it are not uncommon among the Huronian bands in various parts of the territory.

Hematite in bands, associated with sandstones, shales, and trap, is found on Long Island, Hudson's Bay; and loose pieces of this ore are often met with on the eastern coast. A promising deposit of hematite has been opened on Big Black Island, in Lake Winnipeg. Two years ago, Captain H. P. Dawson, R.A., sent me a fine specimen of foliated specular iron from a vein on the northern bay of Great Slave Lake.

Clay-ironstone is found on Melville Island, according to Mr. Charles König (in the Supplement to the Appendix of *Captain Parry's Voyage of* 1819–20). Small quantities of it, in the form of nodules and thin layers, occur in many places in the Cretaceous and Tertiary marls of the northwest territories. In 1875, I discovered a large deposit of this ore, passing into limonite, at the foot of the Grand Rapid of the Mattagami River, a short distance southwest of the head of James' Bay. There are indications of its existence in

considerable quantities in various places among the Devonian rocks to the southwest of this bay.

But probably the most extensive deposit of iron-ore in the territories under description is that of manganiferous spathic ironstone on the Nastapoka Islands on the east side of Hudson's Bay, described in my report for 1877. The ore occurs as a thick band, divided into layers of a few inches, overlying the quartzites and shales and running through all the islands of the southernmost ninety miles of this chain. The dip of the strata is low; and the ore, broken up by the frost, forms much of the surface of these islands, there being no timber or soil. Dr. Harrington has analyzed specimens of the ore from different islands and found it to contain on an average about 50 per cent. of carbonate of iron and 25 per cent. of carbonate of manganese. It would therefore be a valuable ore for the manufacture of spiegeleisen.

*Copper.*—The native copper of the Coppermine River is described as occurring in amygdaloid trap, and, from private accounts which I have heard, it would appear to exist in large quantities. I have found small veins containing copper pyrites on Long Island and one of the Ottawa Islands in the northeastern part of Hudson's Bay. As a set of rocks resembling the copper-bearing series of Lake Superior is largely developed on these islands and the Eastmain coast, copper may be here looked for with a prospect of success. Some of the specimens of granular iron pyrites which I have obtained from the northwest shore of the Bay look as if they contained a small percentage of copper. The quartzites of Marble Island are stained with the green carbonate in some places. Copper pyrites, in small quantities, has been found in the Huronian rocks in various parts of the territories under consideration, and a more promising deposit was described by the late Mr. James Richardson, some miles southwestward of the now celebrated Lake Mistassini. Two quartz veins in Huronian greenstone at the Bruce and Wellington Mines on Lake Huron, yielded sulphuretted copper ores to the value of $3,300,000 between the years 1847 and 1875. Captain Sir John Ross says that he "found copper-ore near Agnew River and Lord Lindsay River," but he does not state what variety of ore it was.

*Lead.*—Among the rocks of the Manitounuck series on the east side of Hudson's Bay, a band of drusy bluish-gray dolomite, about twenty-five feet thick, was found on both sides of Little Whale River and at Richmond Gulf. This band contains a good deal of galena in the form of bunches, some of which would weigh about

100 pounds. Galena has been found by Mr. E. B. Borron in veins in Huronian rocks at Lake Mattagami, in the southern part of the basin of Moose River.

*Zinc*, in the form of blende, is found in small bunches among some of the rocks of the Manitounuck series. Large workable masses of blende occur north of the Battle Islands, Lake Superior, in hornblende schist.

*Molybdenum.*—A specimen of molybdenite was presented to me at Great Whale River, which was said to have been found in the neighborhood. Specks and scales of this mineral are not uncommon in veins in the Huronian series.

*Silver.*—The galena of Richmond Gulf was found by Dr. Harrington to contain 12.03 ounces of silver to the ton of 2000 pounds of ore. The same gentleman found silver in small quantities in iron pyrites from a vein in gneiss near the mouth of Great Whale River, and in the same mineral from another vein cutting dolomite, near Cape Jones. As the rocks of the Manitounuck series appear to correspond with the silver-bearing formation of Lake Superior, deposits of this metal may reasonably be looked for on the east side of Hudson's Bay. Nuggets of native silver have been found with those of gold in some of the upper branches of the Peace River. Copper-ores which have been discovered in the Rocky Mountains, near the line of the Canadian Pacific Railway, contain a notable quantity of silver.

*Gold.*—Traces of this metal were found along with the silver by Dr. Harrington in the pyrites of the two localities which have just been referred to. Specks of gold are mentioned by Professor James Tennant as occurring in quartz which had been brought from Repulse Bay, which lies to the north of Hudson's Bay. At the Huronian mine, north of the height-of-land and west of Thunder Bay, Lake Superior, gold is found in promising quantities in a large quartz vein cutting Huronian schists, which has been worked to some extent; and a stamp-mill has been erected at the mine. It is met with, as specks and small nuggets, also in a quartz vein, at Partridge Lake, a short distance northward of the last-named locality. There is reason to believe that to the west of the lower part of the Mackenzie River, a promising region for gold and silver exists. From private sources it has been ascertained that gold has been washed from the sand and gravel of some of the upper branches of the Youkon and the western tributaries of the Liard; and also of the Rat River, which enters the west side of the delta of the Mackenzie.

The fine gold found in the bed of the North Saskatchewan, especially about Edmonton, is washed out of the drift; and it may have had its original source in the auriferous upper parts of the Peace or Liard valleys, having come thence during the glacial period.

Although it is probable that it will be many years before the cheaper and more bulky of the non-metallic minerals of this vast wild region will be sought after, still, as we never know what circumstances may arise to make them valuable, any facts concerning them are worth recording in advance of the settlement of the region. The knowledge of their existence may sometimes prove a factor in the projecting of railways or in otherwise promoting the development of the country.

*Gypsum.*—Banks of gypsum from ten to twenty feet high occur on both sides of the Moose River, between thirty-one and thirty-eight miles above Moose Factory, which is situated at the southwestern extremity of James' Bay. The upper part is mixed with marl, and only the lower ten feet consist of solid gypsum, which is mostly of a light bluish-gray color. A small proportion is nearly white. A similar deposit of gypsum is reported to occur near the shore of James' Bay, between Moose Factory and Fort Albany. I found a fragment of the mineral last summer among the igneous rocks of the Ottawa Islands in the northeastern part of Hudson's Bay. Sir John Ross reports its occurrence at North East Cape. In Manitoba an impure variety has been found in thin layers in the Cretaceous marls of the Riding Mountains; and nodules and crystals of selenite may be found in these rocks, in almost any part of their distribution in this province and the northwest territories. On the Peace River, at a place called Peace Point, about sixty miles from Fort Chippewyan, at the west end of Athabasca Lake, the cliffs, which are of Devonian age, are largely made up of gypsum. It is also said to occur in considerable quantities a short distance westward of the natural salt deposits of Salt River, a small western tributary of the Slave River, about midway between Lake Athabasca and Great Slave Lake.

*Salt.*—At the locality which has just been referred to, salt of excellent quality, resulting from the evaporation of brine flowing on the surface, is found in considerable quantities, in crystals about the size of those of Liverpool salt. It is shovelled directly into the bags in which it is taken to all parts of the district. At a place called La Saline, about half a mile east of the Athabasca River and thirty-five miles below its junction with the Clearwater River, a

white incrustation of salt is deposited from brine flowing over a bank composed of a black indurated mixture of sand and asphalt. Excellent salt was formerly manufactured from brine issuing from Devonian rocks at the northwestern and also at the southwestern extremity of Lake Winnipegosis. Springs of weak brine issue from the banks of the White Mud River above Westbourne in Manitoba. The Devonian rocks are extensively spread in the northwest territories, and it is to be expected that, when the time comes to require it, salt will be found by boring in many localities.

*Soapstone.*—The Eskimo both of the northwestern and the eastern sides of Hudson's Bay, as well as those of Hudson's Strait and the coast of Labrador, have been accustomed from time immemorial to make their pots and lamps out of this rock, which they find in various places among the gneisses and crystalline schists of these regions. It occurs in abundance at Red Lake, east of Lake Winnipeg, and again near Falcon Island on Lake of the Woods. I have also met with it on the Mattagami River, about twenty miles below Kenagamisse Lake.

*Lignite* is well known to occur extensively in the Cretaceous and Tertiary strata of our northwest territories, all the way from the United States boundary line to the mouth of the Mackenzie River. The most easterly localities are on the Souris River in southern Manitoba and on the Swan River near the northwest extremity of Lake Winnipegosis. The quality of these lignites varies greatly. As a general rule, the nearer we approach the Rocky Mountains the better it becomes. Wherever the beds are disturbed or tilted, the quality is improved. In the Rocky Mountains, a bed of semi-anthracite has been discovered near the line of the Canadian Pacific Railway. Beds of lignite are found in the drift on the Mattagami, Albany and Rainy Rivers and on the southwest side of the Lake of the Woods.

*Coal,* in rocks belonging to the Carboniferous system, is reported by the Arctic explorers to have been found in workable seams in Banks' Land and the islands of the Melville Archipelago.

*Anthracite.*—When on the east coast of Hudson's Bay, I was presented with a number of small specimens of a very fine variety of anthracite, said to occur on Long Island, about four miles from its southern extremity. Judging from its appearance and from the very small percentage of ash which it contains, it has probably resulted from the alteration of a mineral like albertite (*Report*

*Geol. Survey of Canada*, 1877–78, page 24 C.). It has a bright lustre and a highly conchoidal fracture. Mr. Hoffman found it to contain, fixed carbon 94.91, volatile and combustible matter 1.29, water 3.45, ash 0.35, in 100 parts. Some one has remarked that this anthracite has been "probably washed on shore from some vessel." Among the reasons why this could not have been the case, I may mention that up to the time of its discovery, no vessel had ever carried any anthracite into Hudson's Bay; anthracite, if thrown into the sea would sink; the composition of this mineral is different from that of any other known variety; and lastly, it does not occur on the sea-shore at all, but in the interior of the island.

*Petroleum* and *asphalt* have long been known to occur in abundance along the Athabasca and Mackenzie Rivers. Their mode of occurrence was investigated in 1882 by the writer and described in the Annual Report of the Geological Survey of Canada, pages 14 to 23 C C. The petroleum appears to come up from the Devonian limestones, and it saturates and blackens a great thickness of sandy Cretaceous strata, which immediately overlie the former, through a great extent of country. On the Athabasca, these black asphaltic sands form banks, extending for miles along the river and sometimes nearly 200 feet high, from which "tar" is constantly oozing. Thickened petroleum or asphalt has been found in various places on Great Slave Lake, along the Mackenzie River and on the upper Peace River. It is said to have been noted also on one of the upper branches of the South Saskatchewan. The bituminous Devonian limestones of the Abittibi River, near the head of James Bay, contain indications of petroleum.

*Mica* of good quality and in fair-sized sheets is found on the north side of Hudson's Strait, and specimens of it are brought by the Eskimo to every passing visitor. These people also report the existence of sheet-mica on the northwest side of Hudson's Bay, and it was said that some years ago a vessel was loaded with it at Chesterfield Inlet.

*Graphite.*—Eskimo from the north side of Hudson's Strait brought me specimens both of good amorphous and pure foliated graphite, and reported it to exist there in abundance (see *Report* for 1884, p. 24 D D.). A fine-grained variety of graphite is found near Fond du Lac on Lake Athabasca. Plumbaginous schists, containing a large proportion of graphite, have been met with among the Huronian rocks near the north shore of Lake Superior.

*Asbestus.*—This mineral occurs in small quantities near Little

Whale River and on the Ottawa Islands in the northeastern part of Hudson's Bay. Fine specimens of it are found in hornblende schists at Rat Portage, where the Winnipeg River leaves the Lake of the Woods, but the quantity seems too limited to be worth working. I have also obtained specimens of it from both sides of Lake Nipigon.

*Chromic iron* is mentioned by Richardson as among the minerals of the northern Mackenzie River country.

*Apatite* has been detected near the Coppermine River and on Trout Lake in the southern part of the basin of Moose River (see *Geol. Survey Report* for 1881, p. 6, C.).

*Iron Pyrites.*—The Eskimo of the west side of Hudson's Bay have brought me numerous specimens of granular pyrites which appear to be derived from large veins. They state that they find it in different places between Chesterfield Inlet and Nevil Bay. A mass of this mineral, apparently of workable extent, occurs on Scottie Island in Lake of the Woods, and good specimens have been sent me from a rapid in the Mattagami River. It has been noticed in small quantities in hundreds of localities throughout the Territories.

*Lime.*—The Devonian and Silurian limestones of the western, and the dolomites of the Manitounuck or Nipigon formation of the eastern, side of Hudson's Bay afford abundance of good stone for burning into lime. Good material for this purpose is also obtainable everywhere among the Silurian and Devonian rocks which fringe the Laurentian nucleus all the way from Minnesota to Great Bear Lake. Irregular beds or masses of dolomite, often of considerable thickness, are found among the Huronian strata of Lake of the Woods, of Red Lake, to the north of it, and elsewhere.

*Hydraulic Cement.*—Beds of ferruginous and argillaceous dolomite, which would evidently answer for calcining to form hydraulic cement, occur on some of the islands on the east side of Hudson's Bay near Great and Little Whale Rivers.

*Building Stones* are abundant among the rocks which have been already mentioned as suitable for burning into lime. The walls of Fort Prince of Wales, at the mouth of the Churchill River, were faced with blocks, four feet long by two feet thick, cut out of the gray argillaceous quartzite of the neighborhood. The harder quartzites of Marble Island on the west, and of the Manitounuck group on the east, side of the Bay occur in blocks of good shape and size for building. A handsome red granite is met with on

Nottingham Island and on the east shore of Hudson's Bay, south of Cape Wolstenholme.

*Glass Sand.*—The pure white varieties of the quartzites last referred to would answer for glass-making. A beautifully white sand is abundant at the Methy Portage and along the Clearwater River, Athabasca District.

Fire-clays and clays for brick-making, moulding-sand, shell-marl for manure, ochres, peat, flagstones, roofing-slates and other substances found in various parts of the Hudson's Bay Territories might be added to the foregoing list.

---

## *THE MANUFACTURE OF FIRE-BRICK AT MOUNT SAVAGE, MARYLAND.*

BY ROBERT ANDERSON COOK, A.M., MOUNT SAVAGE, MARYLAND.

THE subject of refractory materials occupies such an important position in all metallurgical works, and particularly in those of iron and steel, that any data concerning it must be of interest to the metallurgist. No apology is needed, therefore, for this attempt to describe the mining of fire-clay and the manufacture of fire-brick at one of the largest establishments in this country.

Mount Savage is a small village situated in the northwestern part of the Cumberland coal basin, on the Cumberland & Pennsylvania Railroad, and at the foot of Savage Mountain, from which the village takes its name.

Fire-brick have been manufactured here almost, if not quite, as long as in any place in America; and as the brick are still shipped to nearly half the States in the Union every month, the manufactory is probably the most generally known.

In the year 1837, a company was formed called the Maryland & New York Coal & Iron Company. It built two blast-furnaces, the ruins of which still remain. It was in the construction of these furnaces that the first fire-brick made here were used; and though the iron works ran but spasmodically, the brick works have been in constant operation ever since.

From 1837 until 1846, the Maryland Coal & Iron Company, from then until 1848, the Lochiel Iron Co., and from 1848 until 1864, the Mount Savage Iron Co., ran the brick-works, and in

connection with them the blast-furnaces and extensive rolling-mills. In 1864 the Consolidation Coal Co. ran the entire works; and it was not until 1868 that the iron manufactory was given up, with the exception of the foundry. In 1870 The Union Mining Co. of Allegheny county was formed, and is now engaged in the manufacture of bricks from the mine which was opened about 1841.

*The Clay Mine.*—The mine is situated on the south side of Savage Mountain, three miles from the works by the tram-road. The bed of clay crops out along the summit of the mountain, and runs nearly northeast and southwest. The only other mine on this bed is a very small one, two miles southwest from that of the Union Mining Co. The clay from this mine is brought to Frostburg, where it is manufactured into brick.

The large bed was first opened on the outcrop, and for a number of years all the clay was dug from open pits, and hauled at great expense down the mountain in wagons to the works. Finally, when this method of mining had been carried on as long as was economical, the mine began to be worked systematically, and levels were driven on the outcrop, on one side, wherever it could be reached by reason of the formation of the hill. From this level, galleries were driven at an angle up on the bed, clear through to the old workings. Chambers were driven out from these galleries, connecting the galleries as often as the nature of the ground would permit. When these chambers are all driven through, that part of the mine is robbed of as many of the pillars between the chambers as it is practicable and safe to remove. There are several of these levels driven, the last one about 100 feet below the next above, and as the bed dips about one foot in every four on an average, one can calculate on the amount of clay each level will yield. From the present outlook there is enough to run the works for a great many years.

At the time this more systematic mining was begun, some cheaper mode of transportation was also sought. First, a wire tram on the English system was tried, consisting of an endless wire rope, with buckets of the capacity of fifty pounds, and a stationary engine of eight-horse power at the bottom. This plan involved much trouble, and never could supply the requisite amount of clay; and when winter came, with its extreme cold and snow, the plant was practically useless. Then the regular three-rail incline was adopted, which is in common use in this coal region, and which has worked well ever since. The only peculiarity of this incline is its great

length. It is a mile and a quarter long, and the rise from the bottom to the top is 1240 feet. Six cars run upon it at a time; three loaded ones coming down haul up the three empty ones. The rope is of steel, five-eighths of an inch in diameter, and runs over two shrive wheels twelve feet in diameter, on each of which is a band brake. One man to run these brakes, two men to load, one man to unhook at the bottom, and one to look after the rollers on the incline, are all that are necessary to run 100 tons of clay per day. The cars when empty weigh 1800 pounds, and two tons of clay are loaded on each car. It takes seven minutes, on an average, to run one trip. This is said to be the longest gravity road of its kind in the world. From the bottom of this incline, the loaded cars run down by gravity on a tram-road to the brick-yard, and the empty cars are hauled back by mules to the foot of the incline.

The bed of clay lies at the very bottom of the coal-measures of this basin. On top of the clay lies an 8-inch bed of coal; beneath it lies from three to four feet of shale; and then comes the conglomerate rock which marks the boundary of this basin. The bed of clay varies from eight to twenty feet in thickness.

The clay is divided into two varieties, the hard and the soft; and these are distinguished by their physical properties. One of these varieties is of a medium gray color, shading almost to black. This clay is very hard, and rattles like crockery when thrown into the chutes. It has a distinct, though not regular, conchoidal fracture; it is non-plastic unless ground to an impalpable powder, and does not crumble much when exposed to the weather in heaps, being affected for only about three or four inches from the surface though exposed for years. In parts of the mine this clay, when finely broken, is sharp enough to cut one's hands.

The other variety is a very plastic clay, of much lighter color, weathering very rapidly, and in one season's exposure crumbling to powder.

The peculiarity of this deposit is, that the two clays are so intermixed in the same bed, and in such a way, that in the present development of the mine there is no accounting for the difference in structure of the clay. In one place the bed will be full from roof to floor of hard clay, and in another place, within a few feet of the former, the clay will all be soft. These sudden changes cannot be accounted for. Usually, the soft clay lies on top of the hard, and acts as a sort of protector for it, keeping off the coal-water. In some places, again, there is a gradual change from one to the other,

from hard to soft and back again; and often the hard clay lies between layers of the soft. This is what causes the difficulty in the mining work and makes it seem irregular; for where the hard clay is struck small pillars and large chambers are made, and *vice versa*.

The impurities in this clay are much the same as in all other clays, except that they are fewer and smaller in amount. There are some balls of iron-ore found in the bottom of the bed, but these can readily be seen. The most objectionable impurity is iron pyrites, which is found in the slips of the soft clay, and particularly in the casts of roots in that variety. The detection of this iron pyrites is impracticable until after the bricks have been subjected to the intense heat of the kiln, when discoloration is shown in spots on their surfaces.

The coal which is used at the works is obtained on the property from the coal-measures above the clay. It is mined from a vein twenty-two inches thick, and is brought down to the head of the tram-road by a short incline, and there it is run in with the clay, and trains made up of both are run down to the brickyard.

A good many analyses of this clay have been made, at various times and by different chemists, but it would not be safe to take any one of the various results as a test, for the difference in them is probably due as much to the chemists as to the samples. The following is an average of several results, which will probably give as accurate an analysis as one could obtain:

| | |
|---|---|
| Silica, | 55.75 |
| Alumina, | 33.23 |
| Impurities, | 2.06 |
| Water, | 10.37 |

*The Brick Manufacture.*—The plant for carrying on the manufacture of brick here is as complete as can well be found. There is a foundry and a machine-shop where every machine used in the manufacture of the brick is made. The rollers and pans for crushing the clay, the tempering pans, presses (hand and steam), are all made entirely at the works, so that all varieties of shapes of brick can be made and pressed. The works are complete for turning out all brick from the smallest nine-inch shape, weighing three pounds, to the largest glass-house shapes, weighing three thousand pounds.

The kilns for calcining the clay are built of brick with a boiler-iron shell. They are fifteen feet high and eight feet in diameter, with fire-holes a few feet from the bottom. The top is dome-shaped with a chimney from the center having a damper on top. The clay is charged in through a hole near the top of the dome, and is drawn

out at the bottom of the kiln on iron plates, through two drawing-doors, one on each side of the kiln, twenty tons being the daily product of one kiln.

"The most important constituent is the calcined clay or chamotte. This will not shrink, and possesses the power of union in the greatest possible degree."* These two important qualities have more to do with the production of a brick, regular both in size and in quality, than any other features in the material or process employed.

Another advantage in calcining clay is that it enables one to throw aside any clay in which there are impurities that may have been previously overlooked, since these are much more easily seen when the clay has been burned. The proportion used must, of course, vary with the size of the brick or tile, and the particular use for which it is intended.

From the crushing-pan, which consists of two heavy rollers on a revolving grate, the clay goes by an elevator, through the screens, into a hopper above the tempering-pan. This pan is on the same principle as that used in crushing, except that, instead of having a grate-bottom, it is of solid iron. The clay is carried to the tables of the various moulders by an endless belt. The brick are all moulded by hand. They are dried on a brick floor, heated by flues running the whole length of the yard. When dry enough, they are pressed in hand-presses unless they are too large. In that case they are made in a steam-press at first, and smoothed up by hand when dry enough. No machine for moulding is used here, though it was tried at one time with more or less success, but the bricks were never as even and regular as they are now.

After the bricks are moulded, pressed, and thoroughly dried, they are ready for the kilns. The kilns used here are of two varieties. One is the regular down-draught kiln, rectangular in shape, with fire holes on two sides, and a flue in the bottom, running the whole length of the kiln, having a direct connection with a stack at one end, which gives the draught. Breasts of bricks are built in front of the fire-holes to protect the brick nearest the fire from direct contact with the flame.

The other is a gas-kiln, having some of the peculiarities of the Hoffman, in that some solid fuel is used, and also the heat from the burning bricks dries the brick gradually. In these two points it resembles the Hoffman kiln, but it differs from that in not being a continuous kiln, being rectangular in shape, instead of elliptical,

* *Die Feuerfesten Thone*, von Dr. Carl Bischof, Leipzig, 1876, p. 168 (1).

and using gas for its principal fuel. The kiln is two hundred feet long, forming a tunnel with rows of holes through the roof for the admission of the gas and coal. These holes are provided with iron caps which can easily be removed. Along one side of the kiln is a flue leading to the stack, and flues leading out at right angles to this run across the kiln, so that the gas comes in at the top and goes out at the bottom. At one end of the kiln are fire-holes, and the brick are set at this end first, and the kiln set full for a certain distance. Care is taken to leave a clear space under each hopper in the roof, so that the fuel can go to the bottom. Iron plates are used to shut off the brick already in the kilns from the men setting the bricks, and these plates are made tight by smearing them with clay, making of each section a chamber by itself. The fires are lighted, and burn very slowly for a time until the first brick are gradually but thoroughly heated, when some fine coal is dropped in through the roof. The gas is then admitted through the holes in the roof, and the fire-holes are tightly closed, only enough air being admitted through the red hot bricks for the combustion of the gas.

The gas-producer is on a truck, which runs on a track the full length of the kiln, and as fast as the brick are burned it is moved along the kiln. As it progresses the iron plates are drawn out and placed further up the kiln, adding new chambers. The brick are very gradually dried in this way, and a greater heat is developed with less cost in this kiln than in any of the down-draught kilns, which are heated in the ordinary direct way with coal.

This kiln will hold three hundred thousand brick, and it takes thirty days to burn it from end to end. One man and a boy are all that are necessary to run the producer, except when it must be moved.

The combined product of the works amounts to the equivalent of something over twenty thousand nine-inch bricks per day.

The writer has been employed by the Union Mining Company in making such tests as seemed to be desirable to keep the brick up to the best form for any change which might take place in the market. It was not intended that other clays should be bought to mix with those found here; and from tests made here of brick from other places, and calculations from analyses of other clays, it is doubtful if any could be procured which would be of any advantage in the general run of fire-brick work.

For the calculations in getting at the value of a fire-clay from its analysis, the formula used was one given by a German chemist, Dr.

Carl Bischof, who is a recognized authority on the subject of refractory materials, and whose investigations on the subject have been carried out and verified to some extent in this country. He divides the clay into two parts, the silica and alumina constituting the refractory part, and the impurities the fluxing part. Dr. Bischof, in this formula, uses the impurities as a whole, but in another he divides them according to their relative strength as fluxing agents.

Taking the alumina divided by the total impurities as a dividend and the result of the silica divided by the alumina as a divisor, the quotient will be a measure of the refractoriness of the clay as compared with that of another clay treated in the same way. Calling RO the impurities, the formula will be as follows:

$$\frac{Al_2O_3}{RO} \div \frac{SiO_2}{Al_2O_3}$$

As small a difference as 0.05 between the quotients thus obtained for two different clays indicates a difference in refractory quality which, other things being equal, will show itself in a furnace-test.

These calculations are of great use in comparison of different clays, but the result one might expect from them may be entirely changed when the clays are made into brick. The physical qualities of all clays must be tested before an absolutely perfect comparison can be made. A sample of the same clay being used by two different brick-makers, yet the one brick made from it may not be as refractory as the other, though the sample may have been thoroughly mixed; for if in one case the clay be coarsely, and in the other finely, ground, the coarse one will stand a great deal more heat than the other before it vitrifies to a homogeneous mass.

This has been often observed before; and the writer has found it perfectly true as regards this clay, that the more finely it is ground, the less refractory it becomes. At the same time, the more finely it is ground, the stronger and harder the brick becomes, the more abrasion it will stand, and the less likelihood there is of its being broken in handling. Though refractoriness is an essential of fire-brick, yet it is not the only one.

For the various positions in which the brick are placed, and the duties they are expected to perform from the upper part of a blast-furnace where the heat is low, and the abrasion of stock is the greatest element in the destruction of the brick, to the ports of an open-hearth steel furnace, where intense heat is the most destructive element, particular mixtures of clays should be made, to get the best results from raw materials.

The greatest trouble of a brick manufacturer is that he cannot be sure for what purpose the brick will be used, or in what position in the furnace they will be placed. Another trouble is to find out where the fault lies, when complaint is made. This is almost impossible. It may be in the construction of the furnace, or in bad bricklaying, or in the grade of the brick, or that the brick were not hard-burned. And if a sample lot of brick is sent to a mill to be tested the chances are that when the superintendent is asked how the brick stood the test, he will have forgotten all about them. The only way for a manufacturer to test the brick, is to build a furnace and test them himself, and to do this under as nearly, as possible, the same conditions as those under which they will be used in practice.

The furnace used by the writer for making such tests had nearly the form of a puddling-furnace. One-half of it was built of one mixture and the other half of another, running through the furnace from end to end. Bridge-wall, roof, side-wall and neck would show how the brick stood in each position. From the results of the tests a fair comparison could be obtained of the value of the brick. The draught was a direct one to the foot of a large chimney, and the coal used was a mixture of the best Cumberland coal and our own. A brick of the mixtures used in building the furnace was taken as a standard. One of these bricks, with another, either of some other mixture, or some brick which we wished to test, were placed side by side in the neck of the furnace, which was then fired as hard as possible for a certain length of time. When the furnace had cooled off, the bricks were removed, and the effect carefully noted, particularly as regards shrinkage and vitrification, and the effect of the heat on the furnace was also noticed. The heat in thirty-six hours was intense enough to vitrify any brick, but not enough to destroy them.

As the demand now is for a hard-burned brick, the difficulty of spotted bricks arises. These are bricks which appear to be of poor quality, for though a clay may not contain more than one per cent. of oxide of iron, yet, if it is exposed to a great heat, these spots will show; and, at present, buyers, with the exception of a few who have learned their value, will not take spotted bricks. All the brick from other places, which the writer has tested, will, when exposed to our greatest heat, show some spots, although as they come out of an ordinary kiln, they are free from spots.

The two peculiarities which have made this fire-clay so famous,

are its freedom from impurities, and the fact that it contains such a proportion of silica to the alumina that the brick, after they have been hard-burned, will swell a little instead of shrinking, no matter how much they are heated.

The care which the company has taken in preparing its product for market, has borne profit in the gradual increase of its sales from year to year.

---

## *THE CLASSIFICATION AND COMPOSITION OF PENNSYLVANIA ANTHRACITES.**

BY CHARLES A. ASHBURNER, GEOLOGIST IN CHARGE PENNSYLVANIA SURVEY, PHILADELPHIA, PA.

THE manufacturing and domestic consumers of anthracite are beginning to realize the fact more fully, that the coal purchased for any one year does not seem to burn so freely, does not fire with so little trouble, and does not last so long as that purchased during other years, or *vice versa*. Where coals of different sizes, or from different districts, are offered to the trade by the same or competing salesmen, the question suggests itself, which shall we buy?

Among housekeepers, who are the most numerous class of consumers, though on the smallest scale, distinction is seldom recognized among these anthracites. By other consumers the coals are grouped into those which, when burned, will produce either a white or a red ash, special qualities being arbitrarily attached to each. Others, again, know only of three varieties: (1) Those from the Wyoming and Lackawanna fields, or the coals shipped from the northernmost basins over the railroads running through northeastern Pennsylvania direct to New York—notably, the Delaware, Lackawanna and Western, Delaware and Hudson, and Erie railways; (2) those shipped by the Lehigh Valley Railroad and the Lehigh and Susquehanna division of the Philadelphia and Reading Railroad down the Lehigh Valley; and (3) those shipped over the main line of the Philadelphia and Reading Railroad down the Schuylkill Valley. In special localities, where a favorite coal is largely used, the consumer will speak of one class, composed of his favorite coal, which possibly comes from two or three collieries, with a total aggregate annual production of less than a million tons; and of a second class, composed of the coals from all the other collieries in the anthracite

* This. article was originally prepared for the forthcoming second Report of Progress of the Anthracite Survey. It is contributed to the Institute's *Transactions* by permission in anticipation of its publication in the Survey Report.

region, represented by an annual production of over thirty million tons. This can be noticed particularly in sections of New England, where even an intelligent consumer will sometimes speak of Lykens Valley coal as one kind, and of all other Pennsylvania anthracites as the other kind.

One of the most extensively discussed questions connected with the Pennsylvania anthracite and bituminous regions, and one about which the most unsatisfactory conclusions have been arrived at, has been the classification of the coals. The original division of our Pennsylvania coals into anthracite, semi-anthracite, semi-bituminous, and bituminous, was one founded largely upon their geographical distribution, although the supposed basis was the chemical composition of the coals. These names as they have been indelibly fixed upon coals produced from special sections or individual mines, will always, to some extent, be made use of by the coal trade; they have, however, no scientific value. An interesting discussion of this subject was contributed to the *Transactions** of the Institute, by Dr. Persifor Frazer, and was subsequently published in *Report MM of the Second Geological Survey of Pennsylvania.* As a result, the following classification† is suggested:

| Classes of coals. | Ratio $\frac{C}{\text{Vol. H. C.}}$ : 1. |
|---|---|
| Hard dry anthracite, | from 99 : 1 to 12 : 1 |
| Semi-anthracite, | from 12 : 1 to 8 : 1 |
| Semi-bituminous, | from 8 : 1 to 5 : 1 |
| Bituminous, | from 5 : 1 to 0 : 1 |

In arranging the coals under this classification, and many others proposed, the accidental impurities, such as sulphur and earthy matter, are disregarded in the analysis, and the fuel constituents are alone considered. The fuel-ratio of each coal, or the fixed carbon divided by the volatile hydrocarbon, is represented by the first term of the ratio expressed in the table on page 717. While this classification is probably the best which has been suggested for our Pennsylvania coals, and may be used provisionally as a scientific basis, the coals as at present graded by the coal trade could not be arranged under this or any other chemical classification; and I do not believe that we have sufficient data now at command to suggest a final arrangement which might be considered a scientific rating of the coals, and which would be accepted by the coal miners, venders, and consumers.

The producers and sales-agents classify the coal from individual collieries and from a group of collieries under special heads. The

* Volume vi., page 434.

† See Report AC, page 15.

individual characteristics which are assigned to each separate coal, are supposed to be dependent upon the appearance of the coal, its hardness, the ease with which it burns, and the color of its ash, or the locality from which it is obtained. In the latter case the geographical name is indicative of the recognized character.

Mr. John H. Jones, accountant of the anthracite transportation companies, in his list of collieries, which he has been in the habit of publishing annually until the past year, has noted, in addition to other valuable information, the character, as reported to him, of the coal shipped from each colliery. The kind of coal obtained from each colliery has been often arbitrarily assumed by the trade,* and the fact that two collieries in the same district have been reported as producing the same kind of coal, has been no certain criterion of the true worth of either coal to the consumer.

In some cases the names, which have been given different coals, have been unquestionably adopted on account of the favor which they would thereby secure with the trade and consumers. It has been found by experience, that coal coming for several months, from certain parts of the mines, at an individual colliery, may reasonably be called a red-ash; and, in a number of months immediately following, when the coal is brought from a different part of the mines, it would more fairly be called a white-ash. The name by which such a coal is known, however, may not be changed on account of an absolute difference in the character of the coal, but when the fact is

* A prominent anthracite operator related to me an incident which illustrates the prejudices of the trade in regard to the values of coals. This gentleman was operating a colliery between Shenandoah and Mt. Carmel, which was connected with both the P. & R. R. R., which transported their coal down the Schuylkill Valley, and the L. V. R. R., which shipped their coal to market down the Lehigh River. A contract was made for regular shipments of coal from this colliery over the L. V. R. R. at a time when there was a discrimination of 50 cents between the Lehigh and Schuylkill coals, in favor of the Lehigh, the coal trade generally understanding that Lehigh coal was coal shipped over the L. V. R. R., and Schuylkill coal that shipped over the P. & R. R. R.

The L. V. lateral which took his coal to the main line of the road was temporarily closed, and he was compelled in consequence to fill his orders by shipment over the P. & R. R. R. But a few days had elapsed before his consignee complained of receiving a very inferior Schuylkill coal, instead of the superior Lehigh coal which he had formerly received, and the operator was forced to make a rebate of 50 cents a ton on the coal which he had temporarily shipped over the P. & R. R. R.

It is gratifying to know that among the more *intelligent consumers* no difference is now recognized between certain coals transported through the Lehigh Valley and others through the Schuylkill Valley. In fact several favorite brands of coal, which cannot be excelled, are now shipped almost entirely down the Schuylkill Valley. (See First Rep. Anth. Reg., p. xxxi.)

once established that a change in name will warrant a more favorable reception by a certain class of consumers, and that the sales of the colliery can thereby be increased, it will quickly insure a new classification.

The coals of the producing collieries during the year 1884, have been classified under the general heads* in the following table, which, in addition, shows the number of collieries producing each kind of coal, and the amount in tons, and percentage of each.

| Character of Coal. | Number of Collieries. | Production 1884. Tons. | Percentage of Total Production 1884. |
|---|---|---|---|
| 1. Free-burning White Ash, . | 213 | 17,109,523 | 52.41 |
| 2. Hard White Ash, . . . . | 105 | 9,206,639 | 28.20 |
| 3. Wyoming Red-Ash, . . . | 14 | 1,727,965 | 5.30 |
| 4. Lehigh Red-Ash, . . . . | 11 | 1,510,494 | 4.63 |
| 5. Shamokin, . . . . . | 29 | 1,409,854 | 4.32 |
| 6. Lykens Valley Red-Ash, . . | 8 | 1,145,008 | 3.50 |
| 7. Schuylkill Red-Ash, . . . | 14 | 227,467 | .71 |
| 8. Trevorton, . . . . . | 2 | 116,695 | .36 |
| 9. Lorberry Red-Ash, . . . . | 4 | 101,836 | .31 |
| 10. Bernice White-Ash, . . . | 1 | 86,018 | .26 |
| Total, . . . . . | 401 | 32,641,499 | 100.00 |

Mr. Joseph S. Harris, in speaking of the characteristics of the coals produced from the properties of the Philadelphia and Reading Coal and Iron Company, in the Western and Southern fields, defines the characteristics of many of these different varieties. Although

* This grouping of the coals into ten classes is, without doubt, the best and fairest which has ever been proposed by the coal trade, and is now extensively made use of. In many of the market reports the coals are divided into but two classes, the free-burning and hard white-ash coals. In this connection, the following prices showing the fluctuations of anthracites f. o. b., in New York harbor during 1885, may be of interest:

| | Lump. | Grate. | Egg. | Stove. | Chestnut. |
|---|---|---|---|---|---|
| *Free burning:* | | | | | |
| Lowest, . . . | $3.30 | $3.00 | $3.00 | $3.50 | $3.10 |
| Highest, . . . | 3.45 | 3.25 | 3.40 | 4.10 | 3.60 |
| *Hard white-ash:* | | | | | |
| Lowest, . . . | $4.25 | $3.35 | $3.25 | $4.00 | $3.40 |
| Highest, . . . | 4.75 | 3.50 | 3.40 | 4.25 | 3.75 |

his definitions were not intended to include the coals from the Eastern Middle, and Northern fields, yet, in a general way, they may be considered equally applicable to the special coals from these latter fields. His definitions are as follows:

(1.) *Hard White-Ash.*—"It is in great request for blast-furnace and locomotive purposes, having, to an unusual degree, the qualities of resisting change of form under high heat and pressure, and, owing to its high percentage of carbon, it is valuable for producing steam; but for domestic use on a small scale, and for open-grate fires, it does not ignite readily enough to be a favorite."

(2.) *Free-burning White-Ash.*—"The distinction between it and the hard-burning white-ash coal is, that under such a fire as is ordinarily used for smelting metals or producing steam, the impurities melt or clinker, which is not the case with the harder coal. This practical test is not, however, a very exact one. Some of the anthracites can be clinkered with a strong draft and with a thick bed of fire, and would, by a person who used them under such circumstances, be classed as free-burning, while another, whose method of burning was more economical, would call them hard. Analysis shows that the free-burning white-ash coals are quite as rich in fixed carbon, and that they have even higher heating power, as tested by the amount of water evaporated, than the harder variety, but their limited range of usefulness, which is due to their clinkering, prevents their price rising as high as the hard white-ash coals."

(3.) *Schuylkill Red-Ash.*—"Is easily ignited, easy to keep burning, and where used in open grates makes less floating dust than white-ash coal, because its ash is composed of larger particles, and on account of the oxide of iron, which constitutes its coloring matter, has greater specific gravity than the ash of the white."

(4.) *Shamokin.*—"It follows in hardness, and in ease of ignition, next after the free-burning white-ash coals, and is used still more especially for domestic purposes, its lower percentage of carbon making it ill-adapted for purposes requiring intense heat."

(5.) *Lorberry Red-Ash.*—"It burns with a little flame, and is much in request for domestic uses in the Eastern market."

(6.) *Lykens Valley Red-Ash.*—"It burns with considerable flame, and is greatly liked in the Eastern market for open grates, other domestic uses, and for steam and heating purposes, wherever quick heat is required."

(7.) *Trevorton or North Franklin White-Ash.*—"The coal is pure, but its heating properties are rather low, and it is of so friable a nature that it does not stand transportation well."

The (8) Wyoming red-ash, (9) Lehigh red-ash, and (10) Loyalsock white-ash are not referred to in Mr. Harris's report. The Wyoming red-ash is similar in its general characteristics to the Schuylkill red-ash. The Lehigh red-ash is very similar to the hard white-ash produced from the same region, with the exception of the color of the ash, due to the presence of iron, the same as in the softer red-ash from Schuylkill, while the Bernice white-ash, as a fuel, is rated by many coal men as being similar to the Lykens Valley coal, except in the color of the ash. The geological structure and physical characteristics of the Bernice and Lykens Valley beds are, however, quite different.

The following table shows the amount of the different kinds of coal produced in the different fields, the number of producing collieries in each field from which the different varieties of coals come, and the proportion produced, both in tons and per cent. of total production.

| Coal Field. | Character of Coal. | Number of Collieries. | Production 1884 Tons. | Percentage of Total Production 1884. |
|---|---|---|---|---|
| Northern, | Free-burning White-Ash, | 155 | 14,683.312 | 44.98 |
| | Wyoming Red-Ash, | 14 | 1,727,965 | 5.30 |
| | Total, | 169 | 16,411,277 | 50.28 |
| Eastern Middle, | Hard White-Ash, | 44 | 3,588,190 | 10.99 |
| | Lehigh Red-Ash, | 11 | 1,510,494 | 4.63 |
| | Total, | 55 | 5,098,684 | 15.62 |
| Western Middle, | Hard White-Ash, | 46 | 4,572,762 | 14.01 |
| | Free-burning White-Ash, | 20 | 1,796,738 | 5.50 |
| | Shamokin, | 29 | 1,409,854 | 4.32 |
| | Trevorton, | 2 | 116,695 | .36 |
| | Total, | 97 | 7,896,049 | 24.19 |
| Southern, | Lykens Valley Red-Ash, | 8 | 1,145,008 | 3.50 |
| | Hard White-Ash, | 15 | 1,045,687 | 3.20 |
| | Free-burning White-Ash, | 38 | 629,473 | 1.93 |
| | Schuylkill Red-Ash, | 14 | 227,467 | .71 |
| | Lorberry Red-Ash, | 4 | 101,836 | .31 |
| | Total, | 79 | 3,149,471 | 9.65 |
| Western Northern, | Lykens Valley White-Ash, | 1 | 86,018 | 0.26 |
| Grand total, | | 401 | 32,641,499 | 100.00 |

It is not possible from this grouping of the coals to infer that all of the hard-ash coals are of equal value to consumers,* since the

* In this connection a paper recently read before the Institute by Dr. H. M. Chance on "The Relative Value of Coals to the Consumer," illustrated by a comparison of the coals mined from the Freeport Lower and Kittanning Lower bituminous beds of northwestern Pennsylvania, is of special value.

value of an individual coal as fuel is sometimes more dependent upon the care with which it is prepared, than of the way in which the pure coal ignites, burns, or the color of the ash which it produces. The grouping of the coals in this way, however, is of interest and value as an indication of the general varieties and the amount of each produced.

The pressing demand which has been made upon the Geological Survey of Pennsylvania, for some information as to the fuel-value of different coals, has led to a consideration of what is the composition of Pennsylvania anthracite, as a preliminary step in the investigation.

In ascertaining the fuel-value of a coal, the primary consideration is an estimation of its calorific power, which is generally stated in units of weight of water converted into steam by the combustion of one unit of weight of coal. Analyses showing the percentage of the common constituents of coal, which may be generally classed under the heads of water, volatile matter, fixed carbon, and sulphur, and the amount of coke produced, are all important elements in the practical valuation of a fuel. A study of the characteristics of the coal, directly connected with its physical structure, and a determination of the amount of slate and slaty-coal, which exist in the market-product, resulting from poor mining and imperfect preparation, but which might be economically removed by mechanical separation, are, also, questions of great importance to the consumer.

Professor Charles E. Munroe, in an important paper on "The Valuation of Coal,"* says: "The heat developed by a fuel depends upon the union of the carbon, hydrogen, and other combustible constituents which it contains, with the oxygen of the air, and since, also, the heat produced by the combustion of measured quantities of each of these substances in oxygen has been determined with great accuracy, it would appear a simple thing to determine the calorific power of a coal by subjecting it to an elementary analysis, and calculating from the weights of the elementary substances obtained the heat produced by its combustion; and this method has been followed to a considerable extent in the past, but it has been found in practice to give very erroneous results."

This conclusion is amply borne out by the results of the investigations of many practical chemists and physicists. The tests of Scheurer-Kestner and C. Meunier,† of European and English

* *Proc. U. S. N. Inst.*, vol. vi., No. xiii., page 222.

† *Ann. phys. et chim.*, 4 ser., t. xxi. et xxvi.

coals, show that in calculating the calorific power by the ordinary rule, from analyses of coal specimens, and determining the heat of combustion by direct experiment, the results varied at times as much as 15 per cent.; those based on chemical analyses always being lower than those determined by practical experiment.

The governmental researches made by Professor Johnson in 1842, and those made by Quartermaster-General M. C. Meigs, and reported to the Secretary of War in January, 1882, prove wide differences in the fuel value of many of the Pennsylvania anthracites, and clearly indicate the economy in the purchase of special coals, although at the present time the coal trade makes no reliable distinction between coals which by tests of samples have been shown to have different evaporative capacities.

Mr. William Kent, a member of the Institute who has given the fuel question much attention, admits that chemical analyses and especially ultimate analyses for total carbon, hydrogen, oxygen and nitrogen are valuable guides in estimating the calorific power of coal, when properly burned, although he claims that the results of the tests of Johnson and Meigs indicate a directly opposite conclusion.

The experiments* of Professor William Foster on the composition and destructive distillation of coal, with special reference to the sulphur and nitrogen contained in six specimens of coal, representing the best known types, found in many parts of the United Kingdom, and taken from widely separated localities with the view of making the results as representative as possible, together with a discussion of the paper by Mr. I. Lowthian Bell and Sir Frederick Bramwell and others, are of the greatest value.

A review of the work of the above and other investigators, proves the practical necessity of there being made new and extensive tests as to the proximate composition and fuel-value of American coals.

Such tests the author proposed in 1883,† should be made by the Second Geological Survey of Pennsylvania, but it is doubtful whether any State could afford to make the investigation sufficiently extended to be of the greatest value.

Prof. F. P. Dewey, Curator of Metallurgy, National Museum, within the past year has suggested an admirable plan for making practical tests of American coals, and it is hoped Congress may make necessary appropriations for carrying this work on.

---

* *Proc. Inst. C. E.*, vol. lxxvii., part iii.

† *First Report of Progress in the Anthracite Coal Region*, page xxxi.

In the absence of more elaborate tests, a statement of the composition of Pennsylvania anthracite, as recently determined by Mr. A. S. McCreath for the Geological Survey, and Dr. Charles M. Cresson for the Philadelphia and Reading Railroad Company, will no doubt prove of interest and value to the members of the Institute.

Various percentages of fixed carbon have been assigned by different authorities to a typical anthracite. That which has been most generally accepted has been about 94, with all the accidental impurities, such as those which are generally classified under ash and sulphur, eliminated. Professor Rogers (final report of the First Survey, vol. ii., pp. 969, 970) gives analyses of fifteen specimens of hard dry Pennsylvania anthracites, which show an average: of fixed carbon, 88.05; of volatile matter, 5.81; of ash, 6.14. Eliminating the ash from these analyses, the percentages of the constituents of fuel are as follows: fixed carbon, 93.8; and volatile matter, 6.2.

The range of fixed carbon in the analyses of these fifteen specimens was from 94 to 80; the specimen showing the maximum being obtained from near Pottsville, and that showing the minimum from near Pine Grove, both from the Southern field in Schuylkill County. The range in volatile matter in the fifteen analyses is from 1.40 to 9.53; the minimum amount being in the same Pottsville specimen, and the maximum in a specimen from Black Spring Gap. The range in ash was from 2.90 in a specimen from Tamaqua, to 12.28 in the Pine Grove specimen. These results are certainly misleading, for it has been a long-recognized fact, that the coals obtained in the Southern field do not contain the highest percentages of fixed carbon.

Taylor (*Statistics of Coal*, 2d ed., p. 609) gives analyses of a number of Pennsylvania anthracites reported from various sources. Twelve specimens from the Panther Creek basin, between Mauch Chunk and Tamaqua, show the following:

| | Average. | Maximum. | Minimum. |
|---|---|---|---|
| Carbon, . . . . . | 89.21 | 92.60 | 86.00 |
| Volatile matter, . . . . . | 6.38 | 8.00 | 4.45 |
| Ash, . . . . . | 4.41 | 7.00 | 1.28 |

Six specimens from the Lehigh region gave:

| | Average. | Maximum. | Minimum. |
|---|---|---|---|
| Fixed carbon, . . . . . | 89.00 | 92.30 | 85.34 |
| Volatile matter, . . . . . | 7.05 | 9.60 | 5.36 |
| Ash, . . . . . | 3.93 | 8.73 | 1.28 |

All of these analyses, particularly those given by Taylor, are constantly quoted in numerous descriptions of Pennsylvania anthracite found in technical publications, both at home and abroad. The foreign books and journals have been reporting the higher results; so that the opinion prevails, that the hard dry anthracite mined in the State will range from 90 to 94 per cent. of fixed carbon in the market product. Such is, however, not the case, as the recent analyses made by Mr. McCreath show.

The results which have been reported in the Rogers and Taylor tables referred to, may be taken as those of analyses of mineralogical specimens, which were in most cases carefully selected, either from the mined coal or from special portions of the bed. In no case, it is believed, are the analyses a guarantee of the character of the coal which was being mined or shipped as fuel from the individual localities at the time that the specimens were collected. Even the samples which were collected in considerable quantity, and analyzed and tested for their evaporative capacity by Johnson for the government in 1842, were not, in all cases, fair averages of the coal which could be commanded in the market from the different mines for which his results were reported.

As indications of the composition of mineralogical specimens, the chemical analyses reported by Rogers and Johnson are of little scientific value, without a minute description of the physical characteristics and geological associations of the coal for which they stand. This conclusion could be substantiated by a number of instances to which reference might be made; notably, one where an experienced mining expert was requested to collect duplicate samples from a point in one of the Mammoth bed mines, which, when analyzed, showed the following results:

| | Water. | Volatile Matter. | Fixed Carbon | Sulphur. | Ash. |
|---|---|---|---|---|---|
| Specimen No. 1, . . . | 2.590 | 3.853 | 86.233 | 0.851 | 6.443 |
| Specimen No. 2, . . . | 2.440 | 3.998 | 80.301 | 0.649 | 12.612 |

These two analyses are worthless as indications of the fuel-value of the coal, because it would be unreasonable to suppose that either the first or the second sample, showing such a wide range of composition from the other, could be taken as a fair average of the coal shipped from this mine. Nor are these analyses of scientific value, without certain facts, connected with the occurrence of the coal at this special point, to suggest some reason why such a wide difference should exist.

If the amount of combustible matter in a coal is any criterion of its fuel-value, an examination which has recently been made by the survey shows how ignorant we are as to the actual worth of the different coals which we burn, and how readily we may be deceived by the special characteristics of a coal which we may have noticed, and by which we may have judged of its heating capacity.

In order to test the value to be attached to the judgment of the trade in discriminating between different coals, one of the largest miners and shippers of anthracite coal, who has for a great many years been connected with the mines over a wide area in the region, was requested to name a number of coals, which were credited, by most consumers, with about equal value. Samples of these coals were collected from one or two hundred tons, as they were ready to be shipped to market; the amount collected for each analysis ranging in weight from one to two hundred pounds, which was then reduced by the ordinary methods now commonly used in sampling any mineral product for qualitative and quantitative tests. The number of samples obtained in this way was thirty-three, of which Mr. McCreath reported the following analyses. (See page 718.)

The table of averages (page 717), preceding the table containing the individual analyses, has been compiled from the latter analyses, and shows the mean character of the coal obtained from the more important coal-beds in the Northern field in the vicinity of Wilkes Barre, in the Eastern Middle (Lehigh) field in the vicinity of Hazleton, in the Western Middle field in the vicinity of Shenandoah, and in the Southern field on the property of the Lehigh Coal and Navigation Company, between Mauch Chunk and Tamaqua.

## *Average Composition of Pennsylvania Anthracite.*

| No. of Specimens. | Name of Coal Bed. | Name of Coal Field. | Chemical Analysis.* | | | | | | Specific Gravity. | Percentage of Constituents of Fuel. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Water. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Total. | | Fixed Carbon. | Volatile Combustible Matter. | Fuel Ratio. $\frac{C.}{V.H.-C.}$ |
| 3 | Wharton, | Eastern Middle, | 3.713 | 3.080 | 86.404 | .585 | 6.218 | 100 | 1.620 | 96.56 | 3.44 | 28.07 |
| 5 | Mammoth, | Eastern Middle, | 4.119 | 3.084 | 86.379 | .496 | 5.922 | 100 | 1.617 | 96.55 | 3.45 | 27.99 |
| 2 | Primrose, | Western Middle, | 3.541 | 3.716 | 81.590 | .499 | 10.654 | 100 | 1.654 | 95.64 | 4.36 | 21.93 |
| 5 | Mammoth, | Western Middle, | 3.163 | 3.717 | 81.143 | .899 | 11.078 | 100 | 1.657 | 95.62 | 4.38 | 21.83 |
| 2 | Primrose, ? F.,† | Southern, | 3.008 | 4.125 | 87.982 | .506 | 4.379 | 100 | 1.584 | 95.52 | 4.48 | 21.32 |
| 2 | Buck Mountain, | Western Middle, | 3.042 | 3.949 | 82.662 | .462 | 9.885 | 100 | 1.667 | 95.44 | 4.56 | 20.93 |
| 1 | Seven Foot, | Western Middle, | 3.410 | 3.978 | 80.868 | .512 | 11.232 | 100 | 1.651 | 95.31 | 4.69 | 20.32 |
| 7 | Mammoth, | Southern, | 3.087 | 4.275 | 83.813 | .641 | 8.184 | 100 | 1.631 | 95.15 | 4.85 | 19.62 |
| 3 | Mammoth, | Northern, | 3.421 | 4.381 | 83.268 | .727 | 8.203 | 100 | 1.575 | 95.00 | 5.00 | 19.00 |
| | B. Coal Bed,‡ | Loyalsock, | 1.295 | 8.100 | 83.344 | 1.031 | 6.230 | 100 | —— | 91.14 | 8.86 | 10.29 |

* These analyses are arranged in the order of the percentage of fixed carbon in the fuel constituents.

† Called Red-Ash bed in the Panther Creek Basin.

‡ This coal, according to the classification referred to below, would be called a semi-anthracite, on account of its percentages of volatile matter and fixed carbon. The percentage of volatile matter is not as great, however, as that contained in many of the coals from the Shamokin and Lykens Valley districts, with which the Loyalsock coal favorably compares. The Shamokin and Lykens Valley coals are called anthracites by the trade, and on this basis the trade must consider Loyalsock or Bernice coal an anthracite.

*Composition of Pennsylvania Anthracite.*

| No. of specimens. | Name of Colliery and Coal Bed. | Chemical Analysis. | | | | | | | Physical Properties. | | Percent'e of Constituents of Fuel. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Water. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Phosphorus. | Total. | Color of Ash. | Specific Gravity. | Fixed Carbon. | Volatile Combustible Matter. | Fuel Ratio. C. / V. H.-C. |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. |
| | Northern Coal Field. | | | | | | | | | | | | |
| 1 | Hollenback Shaft, No. 2, at Wilkes-Barre, Baltimore (E) bed | 2.493 | 4.342 | 83.967 | .658 | 8.544 | .010 | 100 | Reddish-gray | 1.614 | 95.08 | 4.92 | 19.33 |
| 2 | D. & H. C. Co.'s No. 5, at Plymouth, Cooper bed | 3.676 | 4.516 | 80.510 | .734 | 10.564 | .002 | 100 | Gray | 1.566 | 94.69 | 5.31 | 17.83 |
| 3 | D. & H. C. Co.'s No. 5, at Plymouth, Bennett bed | 4.092 | 4.288 | 85.329 | .794 | 5.502 | trace | 100 | Gray | 1.546 | 95.22 | 4.78 | 19.92 |
| | Eastern Middle Coal Field. | | | | | | | | | | | | |
| 4 | Jeddo Nos. 3 and 4, at Jeddo, Mammoth bed | 3.862 | 3.242 | 85.319 | .533 | 7.044 | .005 | 100 | Cream | 1.647 | 96.34 | 3.66 | 26.32 |
| 5 | Ebervale No. 2, at Ebervale, Mammoth bed | 4.132 | 3.346 | 85.409 | .511 | 6.602 | .011 | 100 | Cream | 1.595 | 96.23 | 3.77 | 25.53 |
| 6 | Coleraine Nos. 1 and 2, at Coleraine, Wharton bed | 3.728 | 2.750 | 86.916 | .574 | 6.032 | .001 | 100 | Reddish-gray | 1.621 | 96.93 | 3.07 | 31.57 |
| 7 | Coleraine Nos. 1 and 2, at Coleraine, Mammoth bed | 4.304 | 2.996 | 86.712 | .448 | 5.540 | .017 | 100 | Cream | 1.557 | 96.66 | 3.34 | 28.94 |
| 8 | Spring Mtn. No. 4, at Jeansville, Mammoth bed | 4.042 | 2.986 | 88.201 | .387 | 4.384 | .003 | 100 | Cream | 1.651 | 96.73 | 3.27 | 29.58 |
| 9 | Spring Mtn. No. 4, at Jeansville, Wharton bed | 3.756 | 3.376 | 84.727 | .331 | 7.410 | trace | 100 | Reddish-gray | 1.626 | 96.17 | 3.83 | 25.11 |
| 10 | Spring Brook No. 5, at Yorktown, Mammoth bed | 4.254 | 2.846 | 86.258 | .604 | 6.038 | .029 | 100 | Cream | 1.605 | 96.81 | 3.19 | 30.35 |
| 11 | Spring Brook No. 5, at Yorktown, Wharton bed | 3.652 | 3.116 | 87.569 | .451 | 5.213 | .001 | 100 | Light cream | 1.614 | 96.56 | 3.44 | 28.07 |
| | Western Middle Coal Field. | | | | | | | | | | | | |
| 12 | St. Nicholas, at St. Nicholas, Middle Split, Mammoth bed | 2.494 | 4.040 | 80.288 | .604 | 12.574 | .002 | 100 | Cream | 1.677 | 95.21 | 4.79 | 19.87 |
| 13 | St. Nicholas, at St. Nicholas, Bottom Split, Mammoth bed | 3.448 | 3.660 | 81.816 | .798 | 10.278 | .002 | 100 | Reddish-gray | 1.602 | 95.72 | 4.28 | 22.36 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | St. Nicholas, at St. Nicholas, Buck Mtn. bed | 2.500 | 3.956 | 83.297 | .511 | 9.736 | .004 | 100 | Cream | 1.654 | 95.47 | 4.53 | 21.08 |
| 15 | Gilberton, at Gilberton, Seven-Foot bed | 3.410 | 3.978 | 80.868 | .512 | 11.232 | .003 | 100 | Cream | 1.651 | 95.31 | 4.69 | 20.32 |
| 16 | " " " Buck Mtn. bed | 3.584 | 3.942 | 82.026 | .414 | 10.034 | .004 | 100 | Cream | 1.681 | 95.41 | 4.59 | 20.79 |
| 17 | Draper, at Gilberton, Mammoth bed | 2.718 | 3.826 | 81.298 | 1.501 | 10.662 | .018 | 100 | Reddish-gray | 1.666 | 95.50 | 4.50 | 21.22 |
| 18 | " " " Primrose bed | 3.530 | 3.696 | 80.805 | .511 | 11.458 | .002 | 100 | " " | 1.646 | 95.63 | 4.37 | 21.88 |
| 19 | Turkey Run, at Shenandoah, Mammoth bed | 3.510 | 3.622 | 79.660 | .584 | 12.624 | .010 | 100 | " " | 1.654 | 95.65 | 4.35 | 21.99 |
| 20 | Kohinoor, at Shenandoah, Mammoth bed | 3.646 | 3.440 | 82.655 | 1.011 | 9.248 | .018 | 100 | " " | 1.628 | 96.00 | 4.00 | 24.00 |
| 21 | " " " Primrose bed | 3.550 | 3.736 | 82.376 | .488 | 9.850 | .005 | 100 | " " | 1.662 | 95.66 | 4.34 | 22.04 |
| | SOUTHERN COAL FIELD. | | | | | | | | | | | | |
| 22 | No. 3 — Lehigh Coal and Navigation Co.'s collieries. Panther Creek Basin. — Mammoth bed, (E,) | 3.036 | 4.367 | 85.729 | 1.018 | 5.850 | ..... | 100 | Red, white specks | 1.578 | 95.15 | 4.85 | 19.62 |
| 23 | " 3 — Red Ash " (F,) | 2.930 | 4.290 | 88.181 | .556 | 4.043 | ..... | 100 | Cream | 1.574 | 95.36 | 4.64 | 20.55 |
| 24 | " 4 — Mammoth " (D and E,) | 3.106 | 4.270 | 84.442 | .492 | 7.690 | ..... | 100 | Light cream | 1.615 | 95.18 | 4.82 | 19.75 |
| 25 | " 5 — " " " | 3.040 | 4.656 | 83.706 | .542 | 8.056 | ..... | 100 | Light cream | 1.620 | 94.73 | 5.27 | 17.98 |
| 26 | " 6 — " " " | 3.656 | 3.990 | 86.703 | .505 | 5.146 | ..... | 100 | Cream | 1.615 | 95.60 | 4.40 | 21.73 |
| 27 | " 6 — Red Ash " (F,) | 3.086 | 3.960 | 87.783 | .455 | 4.716 | ..... | 100 | Dark cream | 1.595 | 95.68 | 4.32 | 22.15 |
| 28 | " 8 — Mammoth " (D and E,) | 3.320 | 3.713 | 86.611 | .423 | 5.933 | ..... | 100 | Cream | 1.623 | 95.88 | 4.12 | 23.27 |
| 29 | " 10 — " " " | 2.743 | 4.247 | 81.511 | .623 | 10.876 | ..... | 100 | Gray | 1.675 | 95.05 | 4.95 | 19.20 |
| 30 | " 11 — " " (D(?) & E,) | 2.706 | 4.684 | 77.986 | .884 | 13.740 | ..... | 100 | Reddish-gray | 1.688 | 94.33 | 5.67 | 16.64 |
| 31 | " 10, Mammoth (D & E,) Bony coal, No. 1† | 2.733 | 3.933 | 83.115 | .423 | 9.796 | ..... | 100 | Cream | 1.661 | 95.48 | 4.52 | 21.13 |
| 32 | " 10, " " Bony coal, No. 2 | 3.033 | 4.053 | 84.173 | 1.428 | 7.313 | ..... | 100 | Reddish-gray | 1.647 | 95.40 | 4.60 | 20.74 |
| 33 | " 10, " " Bony coal, No. 3 | 2.826 | 4.247 | 82.063 | .458 | 10.386 | ..... | 100 | White | 1.677 | 95.08 | 4.92 | 19.32 |

A comparison of these results with those already referred to, as given by Taylor for the Panther Creek basin, shows wide differences. The two Primrose and seven Mammoth samples reported in the table for the Southern field came from the Panther Creek basin; the average of the two Primrose coals indicating 1.29 per cent., and the average of the seven Mammoth specimens 5.4 per cent., less fixed carbon than Taylor's average; the minimum fixed carbon in the Survey's analyses being 78 as against 86 in Taylor's table, and the Survey's maximum being 88 against 92.6.

These results evidently prove: (1), that the samples which were collected in the past for analyses were not collected with sufficient care; for with the improvements which have been made in the breaker-machinery, and the greater care exercised in the preparation of coal for market, we might reasonably expect to find the higher percentages in the more recent analyses; and (2), the necessity of changing the basis upon which Pennsylvania anthracite has been rated in the past.

The analyses given in the above table are of coals from all sizes (mixed), which were shipped from the different collieries. It is found in practice that after the coal is passed through the breaker and screened into different sizes for shipment, the purity of the different sizes, as regards fixed carbon and ash, is very different. This is indicated by the following analyses of specimens collected from the Hauto screen-building of the Lehigh Coal and Navigation Company.

| Kind of Coal. | Water. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Total. | Color of Ash. |
|---|---|---|---|---|---|---|---|
| Egg, . . . | 1.722 | 3.518 | 88.489 | .609 | 5.662 | 100 | Light Cream. |
| Stove, . . . | 1.426 | 4.156 | 83.672 | .572 | 10.174 | 100 | Cream. |
| Chestnut, . . | 1.732 | 4.046 | 80.715 | .841 | 12.666 | 100 | Cream. |
| Pea, . . . | 1.700 | 3.894 | 79.045 | .697 | 14.664 | 100 | Cream. |
| Buckwheat, . | 1.690 | 4.058 | 76.918 | .714 | 16.620 | 100 | Cream. |

These coals are separated into different sizes according to the mesh of the screen over which they pass. The sizes noted in the above table passed over and through sieve meshes of the following dimensions:

| | Inches. | Inches. |
|---|---|---|
| Broken or grate, | through 4 | over 2.5 |
| Egg, | " 2.5 | " 1.75 |
| Stove, | " 1.75 | " 1.25 |
| Chestnut, | " 1.25 | " .75 |
| Pea, | " .75 | " .50 |
| Buckwheat, | " .50 | " .25 |

In preparing the coal for market, pieces of what is known as *bony coal* are picked out as worthless and thrown on the dirt bank. The lustre of this coal is dull, and it has a cannelly appearance; much of it is believed to be as good a fuel-coal as that which is shipped from the same colliery to market. In fact, analyses recently made of three specimens* of this bony coal, from a certain colliery, proved them to contain more fuel-constituents than the coal which was sold to the trade.† It has been suggested that the *good* bony coal be called "*cannel anthracite.*"

All the analyses upon which the foregoing statements are based, were made subsequent to the writing of the *First Report of Progress*, and are given in detail in the prefatory letter to that report.

In the State report (GG) on the geology of Lycoming and Sullivan counties, a number of analyses of the Bernice or Loyalsock coal are given. The characteristics of this coal have been questioned from time to time, not only by the coal trade, but by analytical chemists, and in order to obtain some proof as to whether the analyses which have been previously made were of average samples, and indicated the general characteristics of the coal, other samples were collected during the past year, and have just been analyzed by Mr. McCreath, with the following results:

| | "No. 1." | "No. 2." | "No. 3." | "No. 4." |
|---|---|---|---|---|
| Water at 212° F., | 3.670 | .976 | .654 | .650 |
| Volatile matter, | 15.420 | 9.969 | 9.501 | 9.405 |
| Fixed carbon, | 71.341 | 81.236 | 79.265 | 83.691 |
| Sulphur, | .594 | 1.274 | .665 | .909 |
| Ash, | 8.975 | 6.545 | 9.915 | 5.345 |
| | 100.000 | 100.000 | 100.000 | 100.000 |
| Color of ash: | Cream. | Reddish-Gray. | White. | Gray. |
| Fuel ratio, | 1 : 4.63 | 1 : 8.15 | 1 : 8.34 | 1 : 8.898 |

* See *First Report of Progress, Anthracite Coal Region*, page 181.

† An incident was recently related to me by a very intelligent miner, where he was severely reproved by a not over-intelligent mine official, for calling attention to the fact that much good coal was evidently being thrown away on the waste-dump merely because it had a bony or cannelly appearance.

Specimen No. 1 is from what is known as Bed A, which underlies the working seam, and which is not mined. The coal from this bed, which occurs sixty feet below the bed which is mined, is true bituminous, while the coal from the working seam, and whose composition is shown in the analyses of specimens 2, 3 and 4, and in the table on page 718, is a true anthracite, according to the trade-classification, or a semi-anthracite by the classification referred to in the early part of this paper.

The existence of these two beds in nearly horizontal positions, with only sixty feet of rock between them, and under geological conditions more nearly resembling those found in the Pennsylvania bituminous than in the Pennsylvania anthracite region, is unique.

A study of the Bernice anthracite bed and of the underlying bituminous bed, in conjunction with a consideration of the geological, physical and chemical conditions under which the other Pennsylvania anthracites, the Welsh anthracite and the Belgian bituminous beds exist, would seem to lend support to the belief that the change of the original vegetable deposits into anthracite has probably been effected to a great extent through a chemical process, by which a portion of the carbon has been oxidized, forming carbonic acid, at the expense of the combined oxygen ; a portion of the combined hydrogen has been oxidized, forming water ; and portions of the carbon and hydrogen have been combined, forming marsh-gas. The removal of the marsh-gas (carburetted hydrogen) in this way, as pointed out by Bischof, may convert bituminous coal into anthracite.

The heat, which was unquestionably produced in the main Pennsylvania anthracite fields, during the plication of the strata, has possibly helped the process, and the water, which was held by the strata in their semi-plastic condition at the end of the Carboniferous Period when the plication took place, has probably been a potent aid.* The absence of great convolutions in the strata of the Bernice coal-basin would not necessarily invalidate this suggested explanation, since the time at which the Belgian field was plicated and the geological conditions under which it took place, may account for the coal-beds being bituminous rather than anthracite. The existence of two coal-beds, one bituminous and the other anthracite, in the Bernice basin, under the same geological conditions, might be accounted for more readily than the gradual transition of a bituminous bed into an anthracite bed in Wales.

* Daubrée has shown that a small amount of water, raised to a temperature of between 300° and 400° C., will produce rock metamorphism.

The question has been asked, why should the coal-beds of the Pennsylvania anthracite basins be more oxidized than those of the bituminous fields. In reply, Professor Lesley suggests this answer: "The undisturbed western coal-measures consist largely of clay strata; those of the eastern coal-measures consist in a much larger proportion of sand and gravel. This would favor the superior oxidation of the latter." Another important consideration is the fact that the circumstances, subsequent to and during the time in which the vegetable matter which composed the anthracite beds was accumulated, were probably more favorable to this oxidation. While the plication of the anthracite region would not seem to alone satisfactorily account for the origin of the anthracitic character of the coals, yet the time and circumstances under which this plication took place were probably more favorable to the formation of anthracite in Pennsylvania than in Belgium. Many ideas connected with this suggested explanation have been thrown out by a number of noted English and American authorities, whom the author hopes to cite in a discussion of this subject to be published in the future, and who are not noted in this brief reference.

In January, 1885, Dr. Charles M. Cresson, consulting chemist of the Philadelphia and Reading Coal and Iron Company, placed at the disposal of the Geological Survey, for publication, a number of analyses which had been made for his company, and which are given below. These analyses are reproduced here from Dr. Cresson's manuscript tables, and they form a valuable contribution to the Survey Report.

Other analyses are now being made, of the average of whole beds, of samples of 300 pounds, which are drawn from the shutes as the coal stands ready for shipment, and Dr. Cresson has offered to give the Survey copies of them as soon as they are finished.

The first table gives the analyses of samples of the coals which were shipped to market from the individual collieries at the time that the analyses were made, and the second table contains analyses of the different benches of coal composing the individual beds for which the analyses stand. The latter are of great value as indications of the relative fuel-value of the different portions of the several coal beds, and are important guides to the most economical mining of the coal-beds, in order to obtain the best marketable product with the greatest margin of profit; and the former are of special interest to consumers.

## *Analyses of Anthracite Coals and of the Ashes of the same from Forty-two Collieries in the Western Middle and Southern Fields.*

By Dr. Charles M. Cresson.

| Name of Colliery. | Volatile Matter. | | | Fixed Carbon. | Sulphur. | Ash. | Phosphorus. | Color of Ash. | Silica. | Alumina. | Iron. (Sesquioxide.) | Lime. | Magnesia. | Sulphur. | Phosphorus. | Heating Power. (Lbs. water evaporated from 1 lb. coal.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | To 212° F. | To Redness. | Total. | | | | | | | | | | | | | |
| Boston Run | 2.50 | 2.10 | 4.60 | 90.276 | 0.124 | 5.00 | none | | 3.210 | 1.100 | 0.520 | none | none | 0.051 | none | 9.10 |
| Hammond | 3.40 | 1.40 | 4.80 | 89.657 | 0.083 | 5.46 | none | | 3.200 | 1.610 | 0.460 | none | none | 0.047 | none | 10.64 |
| Schuylkill | 3.87 | 1.33 | 5.20 | 85.703 | 0.667 | 8.43 | trace | Pale reddish gray. | 5.200 | 1.503 | 0.597 | 0.100 | 0.113 | 0.027 | trace | 9.79 |
| North Mahanoy | 3.20 | 1.35 | 4.55 | 86.680 | 0.564 | 8.20 | 0.005 | Gray | 5.280 | 1.499 | 0.571 | 0.260 | none | 0.036 | 0.006 | 11.11 |
| Elmwood | 2.70 | 2.55 | 5.25 | 86.244 | 0.376 | 8.15 | none | Reddish gray | 5.210 | 1.806 | 0.614 | 0.160 | 0.113 | 0.040 | none | 10.45 |
| Furnace | 2.80 | 1.65 | 4.45 | 85.774 | 0.445 | 9.33 | 0.001 | Pale reddish gray. | 5.780 | 2.516 | 0.414 | 0.210 | 0.101 | 0.107 | 0.001 | 8.70 |
| Conner | 3.14 | 1.76 | 4.90 | 84.571 | 0.009 | 10.52 | trace | Gray | 6.700 | 3.246 | 0.354 | 0.200 | none | 0.010 | trace | 11.11 |
| Plank Ridge | 3.50 | 1.88 | 5.38 | 84.266 | 0.102 | 10.25 | 0.003 | Gray | 3.760 | 2.792 | 0.428 | 0.180 | none | 0.004 | 0.003 | 6.50 |
| Knickerbocker | 2.50 | 1.88 | 4.38 | 86.465 | 0.335 | 8.82 | none | Pink gray | 6.080 | 1.815 | 0.855 | none | 0.011 | 0.019 | none | 6.90 |
| Gilberton | 2.47 | 1.53 | 4.00 | 88.232 | 0.448 | 7.32 | none | Light gray | 5.590 | 0.262 | 0.818 | 0.080 | 0.004 | 0.023 | none | 9.79 |
| Girard | 2.78 | 1.94 | 4.72 | 85.925 | 0.445 | 8.91 | none | Reddish gray | 6.180 | 1.479 | 0.721 | 0.090 | none | 0.022 | none | 8.50 |
| Brookside | 1.54 | 3.86 | 5.40 | 85.636 | 0.184 | 8.78 | none | Dark yellow brown | 4.810 | 1.401 | 1.759 | 0.020 | 0.004 | 0.049 | none | 8.30 |
| Bear Run | 2.30 | 0.90 | 3.20 | 85.878 | 1.162 | 9.76 | none | Gray | 6.255 | 1.485 | 1.240 | 0.020 | none | 0.095 | trace | 9.79 |
| Preston 3 and 4 | 1.76 | 1.94 | 3.70 | 86.732 | 0.688 | 8.88 | trace | Light red gray | 5.880 | 1.836 | 0.815 | 0.060 | none | 0.112 | trace | 10.23 |
| Turkey Run | 2.77 | 1.23 | 4.00 | 88.331 | 0.619 | 7.05 | trace | Light red gray | 5.790 | 0.327 | 0.383 | 0.240 | none | 0.064 | trace | 12.21 |
| Indian Ridge | 2.50 | 1.88 | 4.38 | 86.299 | 0.721 | 8.60 | none | Light gray | 7.195 | 0.163 | 0.593 | 0.120 | 0.011 | 0.075 | none | 11.77 |
| Shenandoah City | 2.07 | 1.40 | 3.47 | 90.557 | 0.543 | 5.43 | none | Light gray | 4.067 | 0.527 | 0.346 | 0.170 | none | 0.067 | none | 12.21 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| West Shenandoah | 2.04 | 0.76 | 2.80 | 87.330 | 0.570 | 3.30 | trace | Light gray | 5.915 | 1.956 | 0.379 | 0.040 | none | 0.049 | trace | 11.09 |
| Richardson | 3.27 | 2.13 | 5.40 | 84.671 | 0.037 | 9.88 | 0.003 | Reddish gray | 6.020 | 2.600 | 0.830 | 0.270 | trace | 0.041 | none | 10.67 |
| Thomaston | 3.40 | 2.62 | 6.02 | 84.495 | 0.455 | 9.03 | trace | Reddish gray | 4.790 | 1.830 | 1.920 | 0.200 | trace | 0.279 | none | 10.45 |
| Beechwood | 2.60 | 1.05 | 3.65 | 87.145 | 0.145 | 9.06 | trace | Reddish gray | 4.520 | 3.000 | 1.200 | 0.150 | none | 0.137 | none | 12.21 |
| Pine Forest | 2.42 | 4.28 | 6.70 | 84.226 | 0.051 | 9.04 | 0.004 | Reddish gray | 5.170 | 2.000 | 1.400 | 0.460 | none | 0.045 | none | 10.45 |
| Glendower | 2.35 | 1.70 | 4.05 | 86.252 | 0.004 | 9.68 | 0.014 | Reddish gray | 4.930 | 2.800 | 1.520 | 0.480 | none | 0.012 | none | 10.10 |
| Eagle Hill | 1.90 | 1.28 | 3.18 | 85.777 | 0.126 | 10.90 | 0.017 | Reddish gray | 5.910 | 2.600 | 1.400 | 0.760 | trace | 0.107 | none | 7.90 |
| Colket | 1.70 | 2.10 | 3.80 | 84.652 | 0.400 | 11.14 | 0.008 | Gray salmon | 4.940 | 3.435 | 0.705 | 0.640 | none | 0.307 | 0.077 | 8.50 |
| Pyne | 1.80 | 2.02 | 3.82 | 86.785 | 0.300 | 9.09 | 0.006 | Salmon | 3.910 | 2.606 | 0.595 | 0.620 | none | 0.282 | 0.006 | 10.50 |
| Phœnix Park | 1.80 | 1.76 | 3.56 | 86.452 | 0.300 | 9.63 | 0.008 | Dark salmon | 5.010 | 3.261 | 0.749 | 0.440 | none | 0.249 | 0.008 | 10.89 |
| Wadesville | 1.90 | 1.70 | 3.60 | 88.680 | 0.220 | 7.50 | none | Light salmon | 2.620 | 2.685 | 0.335 | 0.750 | none | 0.203 | none | 10.67 |
| East Franklin | 2.04 | 2.44 | 4.48 | 83.300 | 0.500 | 11.52 | none | Light salmon | 4.300 | 3.519 | 0.661 | 1.430 | none | 0.462 | none | 12.98 |
| Mine Hill Gap | 2.08 | 1.84 | 3.92 | 87.165 | 0.292 | 8.62 | 0.003 | Light gray salmon | 4.760 | 2.455 | 0.496 | 0.240 | none | 0.121 | 0.003 | 9.79 |
| Mt. Carmel Shaft | 2.25 | 2.17 | 4.42 | 86.357 | 0.873 | 8.35 | trace | Gray | 4.640 | 3.410 | 0.256 | none | none | 0.034 | trace | 12.22 |
| Locust Spring | 1.69 | 2.08 | 3.77 | 87.372 | 0.858 | 7.50 | trace | Pink gray | 4.120 | 2.930 | 0.378 | none | none | 0.055 | trace | 12.66 |
| Potts | 1.74 | 1.11 | 2.85 | 87.655 | 0.625 | 8.87 | none | Pink gray | 3.960 | 3.810 | 0.269 | 0.660 | none | 0.189 | none | 12.44 |
| Bast | 1.91 | 1.71 | 3.62 | 86.481 | 0.589 | 9.31 | none | Pink gray | 4.870 | 3.720 | 0.272 | 0.350 | none | 0.063 | none | 11.56 |
| Mahanoy City | 2.50 | 1.68 | 4.18 | 88.621 | 0.085 | 7.11 | 0.004 | Gray | 4.210 | 2.400 | 0.273 | 0.170 | none | 0.043 | 0.004 | 10.90 |
| Bear Run | 2.41 | 1.26 | 3.67 | 86.675 | 0.510 | 9.14 | 0.006 | Gray | 4.950 | 3.420 | 0.569 | none | none | 0.041 | 0.006 | 11.12 |
| North Ashland | 2.87 | 2.11 | 4.98 | 86.888 | 0.310 | 8.12 | 0.003 | Light gray | 5.370 | 2.400 | 0.199 | 0.060 | trace | 0.023 | 0.003 | 10.90 |
| Merriam | 1.80 | 2.51 | 4.31 | 87.036 | 0.110 | 8.54 | 0.004 | Light gray | 5.420 | 2.400 | 0.360 | 0.220 | 0.009 | 0.090 | 0.004 | 12.76 |
| Preston No. 1 | 1.64 | 1.72 | 3.36 | 84.857 | 0.315 | 11.45 | 0.018 | Pink gray | 6.900 | 3.300 | 0.373 | 0.060 | 0.005 | 0.070 | 0.018 | 9.02 |
| Pottsville | 1.32 | 1.19 | 2.51 | 83.856 | 0.423 | 13.20 | 0.011 | Reddish gray | 6.800 | 5.360 | 0.448 | 0.370 | 0.014 | 0.160 | 0.011 | 9.02 |
| Boston Run | ..... | ..... | ..... | ..... | ..... | 8.16 | ..... | ..... ..... | 4.980 | 1.950 | 0.800 | 0.140 | 0.018 | 0.471 | ..... | ..... |
| Hammond | ..... | ..... | ..... | ..... | ..... | 11.40 | ..... | ..... | 6.670 | 3.108 | 0.972 | 0.170 | 0.025 | 0.681 | ..... | ..... |

## *Analyses of Coals from Six Collieries of the Philadelphia and Reading Coal and Iron Company.*

By DR. CHARLES M. CRESSON.

| Name of Bed. | Locust Spring. | | | | | | Boston Run. | | | | | | Ellangowan. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thickness of Bed. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Heating Power | Thickness of Bed. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Heating Power | Thickness of Bed. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Heating Power |
| Big Tracy | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2′ | 5.50 | 75.21 | 3.83 | 15.46 | 9.6 |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2′ | 6.03 | 80.08 | 1.89 | 12.00 | 11.6 |
| Orchard | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2′ | 8.28 | 81.63 | 2.73 | 12.36 | 10.1 |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2′ | 5.18 | 85.88 | 2.61 | 6.33 | 10.3 |
| Primrose | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1′ | 2.90 | 92.21 | 1.53 | 3.36 | 11.0 |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3′ | 3.02 | 91.57 | 1.86 | 3.60 | 8.5 |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1′6″ | 3.84 | 91.61 | 1.93 | 2.63 | 10.4 |
| | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1′8″ | 3.73 | 87.26 | 2.11 | 6.90 | 9.6 |
| | 2′ 2″ | 18.75 | 75.93 | 1.19 | 8.17 | 10.78 | ..... | ..... | ..... | ..... | ..... | ..... | 1′6″ | 2.95 | 87.75 | 2.60 | 6.70 | 12.4 |
| Mammoth | 2′ 6″ | 4.73 | 90.32 | 0.24 | 3.75 | 9.90 | 3′ | 1.88 | 90.53 | 1.14 | 6.50 | 11.22 | 5′9″ | 3.57 | 79.91 | 2.21 | 14.31 | 9.9 |
| | 2′ | 2.35 | 92.69 | 0.14 | 3.95 | 10.20 | 2′6″ | 2.07 | 94.97 | 0.82 | 2.14 | 9.24 | 3′5″ | 1.88 | 94.12 | 2.30 | 1.70 | 10.3 |
| | 3′ 2″ | 2.97 | 87.72 | 0.20 | 8.50 | 10.67 | 7′ | 3.13 | 87.82 | 2.01 | 7.54 | 10.12 | 9′ | 7.23 | 85.64 | 2.20 | 4.93 | 11.7 |
| | 3′ 0½″ | 1.77 | 91.76 | 0.22 | 5.42 | 11.77 | 3′ | 3.60 | 85.23 | 3.37 | 7.80 | 8.58 | 2′ | 4.24 | 75.54 | 3.99 | 16.23 | 9.9 |
| | 4′ 3″ | 4.53 | 90.77 | 0.15 | 3.26 | 10.56 | 6′ | 2.97 | 91.21 | 1.42 | 4.40 | 10.56 | 9′ | 2.16 | 88.37 | 3.54 | 5.50 | 12.7 |
| Seven Foot | ..... | ..... | ..... | ..... | ..... | ..... | 6′ | 2.66 | 88.35 | 1.93 | 7.06 | 10.34 | ..... | ..... | ..... | ..... | ..... | ..... |
| Buck Mtn | ..... | ..... | ..... | ..... | ..... | ..... | 10′ | 3.99 | 81.51 | 4.17 | 10.33 | 9.68 | ..... | ..... | ..... | ..... | ..... | ..... |

| Name of Bed. | Indian Ridge. | | | | | | Mahanoy City. | | | | | | North Mahanoy. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thickness of Bed. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Heating Power | Thickness of Bed. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Heating Power | Thickness of Bed. | Volatile Matter. | Fixed Carbon. | Sulphur. | Ash. | Heating Power |
| Primrose | ..... | ..... | ..... | ..... | ..... | ..... | 5′ | 4.53 | 86.65 | 4.67 | 4.15 | 9.90 | ..... | ..... | ..... | ..... | ..... | ..... |
| | ..... | ..... | ..... | ..... | ..... | ..... | 5′ | 4.68 | 90.91 | 2.81 | 1.60 | 9.24 | ..... | ..... | ..... | ..... | ..... | ..... |
| | ..... | ..... | ..... | ..... | ..... | ..... | 3′ | 3.72 | 90.51 | 1.67 | 4.10 | 0.34 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 7′ | 3.75 | 89.64 | 4.49 | 2.12 | 11.22 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 3′ | 3.62 | 88.14 | 5.93 | 2.31 | 11.66 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 3′ | 8.23 | 84.59 | 1.93 | 5.25 | 10.12 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 4′ | 4.71 | 70.70 | 0.09 | 14.50 | 9.68 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Mammoth | 2′ | 10.21 | 87.74 | 0.65 | 11.40 | 9.90 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 1′ 6″ | 5.61 | 59.58 | 1.93 | 32.88 | 7.04 | 3′6″ | 4.67 | 88.37 | 1.50 | 6.46 | 10.56 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 5′ | 5.34 | 89.65 | 0.17 | 4.84 | 10.78 | 2′6″ | 5.01 | 83.89 | 5.08 | 6.02 | 8.14 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 3′ | 2.99 | 89.88 | 0.25 | 6.98 | 10.12 | 2′ | 6.61 | 84.34 | 2.04 | 7.01 | 10.56 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 7′ | 4.87 | 79.80 | 4.33 | 11.00 | 11.44 | 6′6″ | 3.00 | 89.77 | 2.67 | 4.56 | 10.56 | ..... | ..... | ..... | ..... | ..... | ..... |
| Skidmore | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 7.36 | 84.12 | 1.97 | 6.55 | 10.56 |
| Seven Foot | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5.82 | 76.59 | 2.89 | 15.20 | 4.40 |
| Buck Mtn | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 12.38 | 71.89 | 4.65 | 11.08 | 7.92 |

## *PROPOSED APPARATUS FOR DETERMINING THE HEATING POWER OF DIFFERENT FUELS.*

BY WILLIAM KENT, M.E., NEW YORK CITY.

MR. ASHBURNER'S paper on the Classification and Composition of Pennsylvania Anthracites, read at this meeting, well shows the need of new and accurate determinations of the heating value of these coals. A similar need exists for the determination of the value of bituminous coals, since the variation in quality of the latter is greater than the variation in anthracites. The recent extensive use of liquid and gaseous fuels, "patent" fuels, tan-bark, and other refuse fuels, also makes a necessity for some correct method of determining the relative values of each of these fuels.

Mr. Ashburner has recommended that tests of coals should be undertaken by the Second Geological Survey of Pennsylvania, and Professor Dewey, as stated in Mr. Ashburner's paper, has suggested a plan for tests of American coals, by the Smithsonian Institution, for which an appropriation by Congress will be asked.

It is to be hoped that if any extensive series of tests of coals is carried on under either Government or State auspices, the erroneous methods of test which were followed by Professor Johnson in 1842, and by Quartermaster-General Meigs in 1882, will not be adopted.*

The first requisite in determining the heating-power of a fuel is proper apparatus, such as has not been used in any of the tests of American coals yet reported. In the hope that more accurate means may be used in future tests, the writer desires to call attention to an apparatus which he has designed for the purpose. Not having had opportunity for making a trial of it, nor even of having it criticised by others, he does not offer it as the best possible apparatus; but if it contains any points of value, and leads to the design of still more suitable devices by others, the object of the presentation of this paper will be accomplished.

The tests by Professor Johnson and General Meigs were made by evaporating water into steam in ordinary steam-boilers. A steam-boiler of ordinary construction is not a good apparatus for determining the heating power of a fuel, for the following reasons:

* For a criticism of these tests, see the writer's paper on the Evaporative Power of Bituminous Coals—*Trans. Am. Soc. Mech. Eng.*, vol. iv., p. 249.

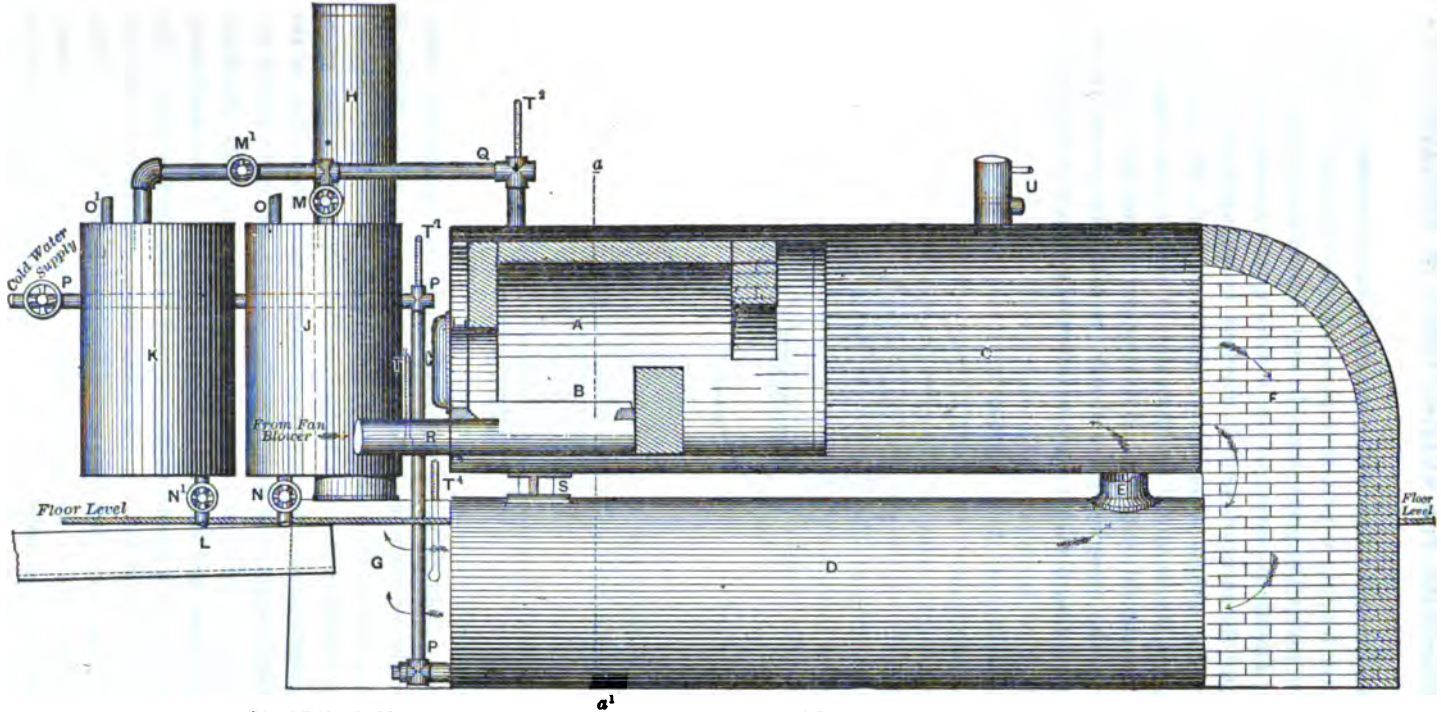
1. We can have no assurance that the fuel is completely burned. In all coals containing volatile matter, the distilled gases may be chilled by the heating surfaces of the boiler, and escape into the chimney unburned.

2. The heat generated by the fuel is carried away in four different portions: *a*, in the steam which leaves the boiler; *b*, in the "entrained" water which leaves with the steam; *c*, in the waste gases in the chimney; *d*, by radiation from the boiler and brickwork. The relative proportion of heat which disappears in each of these four different ways varies every instant, and the measurement of any one of the portions is an exceedingly difficult matter and liable to great errors.

3. The boiler and furnace having a large heat-absorbing capacity in proportion to the quantity of fuel burned during a test, it is difficult to insure that the conditions at the beginning and end of a test are the same; that is, that in addition to the four outlets for the heat of the fuel above mentioned, a fifth part of the heat has not been absorbed by the boiler and brickwork in making them hotter at the end of the test than at the beginning.

The accompanying illustrations (Fig. 1, a longitudinal view and section, and Fig. 2, a cross-section at *a a'*, Fig 1.) sufficiently show the proposed apparatus, in which an attempt is made to avoid to a great extent these sources of error. Its principal feature is that it is not a steam-boiler at all, but only a water-heater. It consists of two sheet-metal cylinders, each 12 feet long, the upper one 4 feet in diameter, and the lower one 3 feet, and connected by a short neck at one end only. The upper cylinder is provided with a fire-box 3 feet 6 inches in diameter and 6 feet long, and its rear end is filled with about 100 two-inch tubes. The lower cylinder is completely filled with two-inch tubes. The fire-box is lined throughout with fire-brick, and contains a grate surface 2 feet wide by $2\frac{1}{2}$ feet long. A hanging bridge-wall of fire-brick is placed in the upper part of the fire-box in the rear of the bridge-wall proper for the double purpose of presenting a hot fire-brick surface to the flame before allowing it to touch the heating-surfaces of the tubes and tube-sheet, and of changing its direction so as to cause the gases to thoroughly commingle and thus to insure complete combustion. In testing highly bituminous coals, it might be advisable to have more than one of these hanging walls, and to give the fire-box a greater length, to more certainly insure complete combustion of the gases. The gases of combustion pass through the tubes of the upper heater,

Fig. 1.

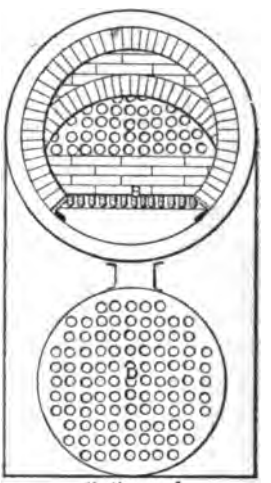



**APPARATUS FOR DETERMINING THE HEATING POWER OF DIFFERENT FUELS, BY WM. KENT**

A, Fire Box.
B, Grate-Bars.
C, Tubes of Upper Heater.
D, Lower Heater.
E, Connection between Heaters.
F, Flue between Heaters.
G, Chimney-connection.
H, Chimney.
J K, Water-measuring Tanks (closed tops).
L, Waste Drain for Hot Water.
M M¹, Admission Valves to Tanks.
N N¹, Emptying Valves.
O O¹, Overflow- and Vent-Pipes.
P, Cold water Supply-Pipe.
Q, Hot water Outlet.
R, Air-Supply Pipe.
T¹ T², Thermometers for Water.
T³ T⁴, Thermometers for Air and waste Gas
S, Support of Upper Heater.
U, Safety-Valve.

then down through a fire-brick connection into the tubes in the lower heater, after leaving which they pass into the chimney. Air is fed to the fire, under the grate-bars, through a pipe leading from a fan-blower. The air is measured by recording the revolutions of the blower, and the measurement is checked by an anemometer in the air-pipe. Its weight should be calculated from the barometric pressure, and its contained moisture should also be determined. Its temperature should be taken before it enters the ash-pit. The temperature of the escaping gases should be taken by several thermometers, the bulbs of which reach to different portions of the chimney

FIG. 2.



*Section a a*[1]

connection. Cold water is supplied to the bottom of the lower heater, at the chimney end, its temperature being taken before it enters, by a thermometer inserted in the pipe. The water supply-pipe may conveniently be attached to the city main. The water passes through the two heaters in an opposite direction to that of the gases of combustion, and escapes at the outlet-pipe at the top of the upper heater, by which it is taken to two measuring tanks, which are alternately filled and emptied. The temperature of the outflowing water is taken by a thermometer inserted in the outflow-pipe. The rate of flow of water through the apparatus is regulated, so that the temperature of the outflowing water does not exceed 200° F. The measuring-tanks have closed tops, which prevent evaporation, small outlet-pipes being attached to the top of each which serve both as

indicators when the tanks are full, and to allow air to escape from the tank when it is being filled with water.

The grate-surface being only 5 square feet and the heating surface about 1000 square feet, a ratio of 200 to 1, or more than five times the usual proportion in a steam-boiler, and the water being much colder than that in a steam-boiler, the gases of combustion should be cooled down to near the temperature of the air supplied to the fire—especially when, as is usually the case, the water supply is colder than the air. For extremely accurate tests, the water might be cooled before entering, by a refrigerating apparatus, or by ice.

The whole apparatus being thoroughly protected, by felting, from radiation, the heat generated by the fuel is all measured in the increase of heat given to the water which flows through the apparatus, and in the increase of temperature of the gases of combustion as taken in the chimney, over the temperature of the air supplied to the fire. This increase, however, being in any case very slight, and the quantity of air being known, the amount of heat from the fuel which escapes up the chimney can be calculated with but small chances of error.

---

## *THE PROCESS USED AT THE COMSTOCK FOR REFINING COPPERY BULLION PRODUCED BY AMALGAMATING TAILINGS.*

BY A. D. HODGES, JR., BOSTON, MASS.

THE process to be described, whatever other merits (or demerits) it may have possessed, certainly proved a financial success under the conditions of the locality where it was introduced and where a refining process had been sought previously in vain. I have ventured to bring it to the notice of the Institute in the hope that it may prove of some interest as a solution of a practical problem, such as is often presented to the metallurgist in the remote mining regions of the West.

The method was used first at the Lyon Mill at Dayton, Nevada, and has been adopted at other tailings-mills on the Comstock. These mills treat two classes of tailings: "sand," or material which has passed previously through the pans of the ore-mills; and "slimes," or the fine clayey material which, coming from the battery, is too light to settle in the tanks inside of the mills but is

caught in large reservoirs outside. The slimes, never having been worked, are naturally richer than the sands; but the assay-values of each class vary considerably among themselves. At the Lyon Mill the sand assayed from $5 to $7 and the slimes from $15 to $25 per ton.

The tailings are amalgamated in combination pans (of wood and iron) with the aid of salt and bluestone. The best results have been obtained when, through the free use of sulphate of copper, the bullion produced has been very base. At Dayton the fineness of the bullion was kept designedly at from 150 to 250.

The amalgam is taken from the canvas strainers and retorted in cylindrical iron retorts, during which process, when properly conducted, the resulting bullion separates into two distinct parts. Next to the retort-body there is a shell of compact and partially fused material, nearly white in color (and hence called locally "white bullion") with more or less of a reddish tinge. On top of this last, in the more central part of the retort, there is a reddish-brown, porous and comparatively brittle mass of what is called (by comparison) "base bullion." The latter is easily crushed and had been roasted and treated with sulphuric acid. But the white bullion had resisted all attempts before made to refine it. It was too dense to allow of crushing, and its composition, about one-half silver and one-half copper, did not permit the successful use of any of the separating processes which had been tried.

The problem presented was to refine the material mentioned by some simple, cheap and quick process which did not require the establishment of any expensive plant or the services of any specially trained workmen, and which would not cause loss of precious metal. For, although the heavy and constantly increasing discount on the value of the silver in this product and the total loss of the copper (which was not paid for) rendered a refining process very desirable, yet on account of the losses incurred in previous trials the general management of the Lyon Mill had become very cautious and skeptical in the matter, and disinclined to incur any more expense in experiments. After some demur, at the end of 1873 a trial on one month's mill-run was allowed. No apparatus or material was used except that already on hand. The retort-bullion was assayed in advance and the assay-returns handed in. At the end of the experiment (during which no attempt was made to keep the fine silver separate) there was a very careful clean-up and the return in melted bullion-bars was compared with the assay reports.

Attached to the mill were sulphuric acid chambers and a bluestone factory. There were on hand a small, decrepit 5-stamp battery for crushing wet the base bullion, a small roasting furnace, dissolving-tubs, crystallizers, and an old refining kettle. I afterwards substituted an iron Chili mill for the battery, and added two silver precipitating vats (using old settlers lined with lead), two or three filter-tubs, and a precipitating room; and, when the furnace was burned out, rebuilt it in a more convenient situation in a room of its own. This comprised all the new plant ever erected.

I give here the result of the first trial as copied from my books. Assays were repeated many times, and made very exactly.

*Assay Returns.*

| | Date. | Ozs. | Assay Fineness. | | | Ounces of Pure Metal. | | | Ounces of Pure Metal. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ag. | Au. | Tot'l | Ag. | Au. | Total. | Ag. | Au. | Total. |
| White Bullion, | Nov. 15, 1873..... | 6,400.7 | 430.55 | 0.65 | 431.2 | 2,755.8 | 4.2 | 2,760.0 | ..... | ..... | ..... |
| | Dec. 2, 1873..... | 6,473.5 | 433.0 | 0.5 | 433.5 | 2,803.0 | 3.3 | 2,806.3 | ..... | ..... | ..... |
| | Dec. 22, 1873..... | 5,511.2 | 477.75 | 0.55 | 478.3 | 2,633.0 | 3.0 | 2,636.0 | ..... | ..... | ..... |
| | Dec. 27, 1873..... | 2,624.4 | 485.75 | 0.55 | 486.3 | 1,274.8 | 1.4 | 1,276.2 | 9,466.6 | 11.9 | 9,478.5 |
| Base Bullion, | Dec. 9, 1873..... | 9,389.5 | 67.15 | 1.95 | 69.1 | 630.5 | 18.3 | 648.8 | ..... | ..... | ..... |
| | Dec. 26, 1873..... | 16,038.0 | 70.05 | 2.15 | 72.2 | 1,123.4 | 34.5 | 1,157.9 | ..... | ..... | ..... |
| | Jan. 1, 1874..... | 11,066.2 | 69.55 | 1.75 | 71.3 | 769.7 | 19.4 | 789.1 | ..... | ..... | ..... |
| | Jan. 6, 1874..... | 15,032.0 | 69.7 | 1.8 | 71.5 | 1,047.7 | 27.0 | 1,074.7 | ..... | ..... | ..... |
| | Jan. 9, 1874 ..... | 10,242.5 | 68.55 | 1.75 | 70.3 | 702.1 | 17.9 | 720.0 | 4,273.4 | 117.1 | 4,390.5 |
| | | | | | | | | | 13,740.0 | 129.0 | 13,869.0 |

*Return in Melted Bullion.*

| Bar. | Date. | Ozs. | Assay Fineness. | | | Ounces of Pure Metal. | | | Ounces of Pure Metal. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ag. | Au. | Tot'l | Ag. | Au. | Total. | Ag. | Au. | Total. |
| 868–869 | Dec., 1873..... | 2,120.0 | 960.3 | 24.7 | 985.0 | 2,035.8 | 52.4 | 2,088.2 | ..... | ..... | ..... |
| 870 | Jan., 1874..... | 997.0 | 966.25 | 3.25 | 969.5 | 944.0 | 3.2 | 947.2 | ..... | ..... | ..... |
| 871 | Jan., 1874..... | 715.0 | 885.5 | 32.6 | 918.1 | 633.1 | 23.3 | 656.4 | ..... | ..... | ..... |
| 872–873 | Jan., 1874.. ..... | 2,023.0 | 964.85 | 3.15 | 968.0 | 1,952.0 | 6.3 | 1,958.3 | ..... | ..... | ..... |
| 1–2 | Jan. 19, 1874..... | 1,966.0 | 917.75 | 14.45 | 932.2 | 1,804.3 | 28.4 | 1,832.7 | ..... | ..... | ..... |
| 3–4 | Jan. 19, 1874 ..... | 1,766.5 | 959.75 | 2.15 | 961.9 | 1,695.4 | 3.8 | 1,699.2 | ..... | ..... | ..... |
| 5–6 | Jan. 19, 1874..... | 2,075.0 | 976.1 | 2.1 | 978.2 | 2,025.2 | 4.4 | 2,029.6 | ..... | ..... | ..... |
| 7–8 | Jan. 19, 1874..... | 1,650.0 | 967.4 | 2.2 | 969.6 | 1,579.7 | 3.6 | 1,583.3 | ..... | ..... | ..... |
| 9–10* | Jan. 19, 1874..... | 1,812.0 | 584.2 | 1.4 | 585.6 | 1,058.6 | 2.5 | 1,061.1 | ..... | ..... | ..... |
| | Total of bullion returns..... | | | | | | | | 13,728.1 | 127.9 | 13,856.0 |
| | Total by assay as above..... | | | | | | | | 13,740.0 | 129.0 | 13,869.0 |
| | Difference (practically nothing) { ounces, | | | | | | | | 11.9 | 1.1 | 13.0 |
| | per cent. | | | | | | | | 0.086 | 0.85 | 0.99 |

* Clean-up bars.

The process may be summarized as follows:

The base bullion is crushed and roasted dead in a reverberatory furnace to form oxide of copper and metallic silver (and gold).

The white bullion is treated with sulphur in a closed vessel at a low heat, forming sulphide of silver and of copper. This is crushed and roasted to form oxide of copper and sulphate of silver (Ziervogel-process).

The roasted products are treated (separately as a rule) with hot dilute sulphuric acid (chamber acid). All of the copper (oxide) is thus converted into soluble sulphate. The silver sulphate also goes into solution. Moreover as dilute nitrogenous * sulphuric acid dissolves metallic silver to a considerable extent, an additional amount of silver sulphate is obtained in solution. Some of the silver apparently remains oxidized after roasting, and dissolves in common sulphuric acid; that is, acid which has been concentrated. The Omega Refinery used such acid (diluted), but the amount of silver sulphate obtained from the base bullion was much less than at Dayton, where chamber acid was used. A large part of the silver in the roasted products and all of the gold are left as residues in the dissolving tubs, and (after leaching, drying, etc.) are melted in black-lead crucibles to refined doré bullion.

All the sulphate solutions are removed to tanks containing metallic copper, where metallic silver is precipitated. This product melted gives fine-silver bars.

The copper-sulphate solutions, after being freed from silver, when of sufficient strength, as was almost always the case, are drawn into crystallizing vats whence is obtained a fine quality of merchantable bluestone. Weaker solutions are first concentrated and then crystallized. Very weak solutions (wash-waters, etc.), are run into vats holding iron, to recover the copper which is melted into bars and used to precipitate silver. The mother-liquor from the crystallizers is concentrated and recrystallized, the acid second mother-liquor being utilized in the dissolving tubs.

Inasmuch as I have found the correct details of any metallurgical operation, when obtainable, of great value in my practical work, I

---

* By this is meant sulphuric acid containing one or more of the nitrogen oxides. There is much difference of opinion, among those who have written on the theory of chamber-acid, concerning the precise oxides of nitrogen thus occurring; and it is not intended here to express any opinion on that point. The capacity of such sulphuric acid to dissolve silver, is an important matter, which has been ignored in almost all the text-books.

take the liberty of describing the process in full. If I have fallen into the error of too voluminous description, I have at least avoided the fault of giving favorable estimates in the place of actual working results—a fault not wholly unknown in the annals of the profession. In one place only am I open to the charge of "fudging." In the amount of fine silver produced in 1876 I have included quite a number of ounces which really contained a little gold—sufficient to compel its being noted when stamping the bars. This I have done to avoid injustice to the process and to the workmen employed who took a pride in turning out good work and who were sorely troubled at the time at the presence of gold in the "fine silver"—a thing due in the case in question *solely* to what might be included in the Spanish term *Fuerza Mayor;* to that Superior Power with which one does not contend willingly. I think my brethren of the profession who have worked under well-meaning and interested, but not always thoroughly-informed high officials, will understand without further explanation.

In all other cases, including the statement of costs, I have given not what might or ought to have been, but what actually was. The expenses of the refinery were increased by the fact that the retorted bullion from the mill was treated of necessity as it was produced,—in small and varying amounts. Again, the price of certain materials, as acid, for the year 1876, owing to various causes, was higher than usual. But having chosen this year simply because the full data for this period happen to be handy, while those of other years are temporarily beyond my reach, I feel bound by my limitations to record the exact case.

All data given are those of the Lyon Mill, unless otherwise specified.

The terms "white bullion" and "base bullion" are used in their local signification.

Each separate operation was controlled by a system of check tests and weights, which made it practically impossible for any error in working to escape detection.

*Retorting.*—The retorts were charged with about 1700 pounds each of amalgam. The fires were started about four o'clock in the morning, and the last fire was given about six o'clock in the evening. The temperature was raised gradually from the beginning until the quicksilver distilled freely, and was then kept as steady as possible until the distillation was nearly finished, gently increasing toward the end when a hot fire was made, and allowed to burn out.

Variations in temperature are to be avoided after a proper degree of heat has been obtained; also a too hot fire in the earlier stages of the operation, when the charge seems to melt more easily than it does later.

When the retorts are opened (on the following morning) there are found a dense shell of white bullion, and a porous mass of base bullion as before mentioned. The proportions of these two classes (white and base) vary, partly according to the relative amount of silver in the amalgam, and partly according to the manner of retorting (firing). At first efforts were made to lessen the proportion of white metal, in order to diminish the amounts to be sulphurized. But thereby the proportion of fine silver, and the consequent concentration of the gold in the doré bullion, was diminished correspondingly. After considerable experience it was found pecuniarily advantageous to retort thoroughly, and produce as much fine silver as possible without sulphurizing the base metal.

The amalgam was weighed before, and the bullion, both white and base, after retorting. Averaging all the retorts during 1876 and 1877 we have the following figures:

100 *Pounds of Amalgam Yielded*

| | | | |
|---|---|---|---|
| In 1877, from slime-pans, | 4.6 lbs. white, | 9.0 lbs. base, | 13.6 lbs. total bullion. |
| In 1877, from sand-pans, | 2 77 lbs. white, | 11.97 lbs. base, | 14.74 lbs. total bullion. |
| In 1877, from all pans, | 3 24 lbs. white, | 11.22 lbs. base, | 14.46 lbs. total bullion. |
| In 1876, from all pans, | 3 0 lbs. white, | 12.2 lbs. base, | 15.2 lbs. total bullion. |
| Average from all pans, | 3.1 lbs. white, | 11.7 lbs. base, | 14.8 lbs. total bullion. |

The expenses of retorting were charged to the mill.

*Sampling.*—The bullion was removed in one coherent cake from each retort to a low box lined with sheet-iron. From each cake 3 slices, one at the middle and one near each end, about three inches wide, were obtained by cutting the cake completely through with cold chisels in 6 lines across it. Care must be taken to get with each slice everything, dirt and all, belonging to it. This was secured by laying 6 bars of iron, in 3 pairs, under the 6 cutting-lines; everything falling between the two bars of each pair belonged to the corresponding slices. These slices formed the sample.

The samples were cut up into small pieces, the base and the white being kept separate, and sampled down to 6 pounds of white and 5 pounds of base, these amounts respectively forming a charge for the small black-lead crucibles in which the samples were melted and from which granulations were taken and treated as in the regular bullion-assays. All such assays were made fourfold.

Repeated tests, made at intervals during two years and checked in every possible manner, showed this method of sampling to be satisfactory when done carefully, and when the retorted bullion was substantially free from quicksilver. In order to control all operations of working the tailings, as well as those of the refinery, the bullion was sampled and assayed regularly during my stay at Dayton.

After sampling, the remainder of the retort was broken up into small pieces, and the base and the white carefully separated. All dirt went naturally with the base.

*Assaying.*—The fineness of the bullion from the various mills varied greatly, in accordance with the richness of the material amalgamated and the method of treatment. At the Lyon Mill, as before stated, a comparatively steady grade of fineness was sought. The gold followed the copper in its separation in the retort to a great extent, but small fluctuations had no effect. I extract the following from my assay book for the 2 years already mentioned:

*White Bullion.*

Highest silver assay, . . 652 fine (gold here 0.2 fine).
Lowest silver assay, . . 482 fine (gold here 0.4 fine).
Highest gold assay, . . 1.3 fine (silver here 571 fine).
Lowest gold assay, . . trace (silver here 606 and 616 fine).
Average assay, 565 silver, 0.4 gold.

*Base Bullion.*

Highest silver assay, . . 89 fine (gold here 1.9 fine).
Lowest silver assay, . . . 17 fine (gold here 1.3 and 0.7 fine).
Highest gold, . . . . 3.2 fine (silver here 74 fine).
Lowest gold, . . . . 0.4 fine (silver here 49 fine).
Average assay, 37 silver, 1.16 gold.

*Total Bullion.*

Average assay, 148 silver, 1.0 gold.

I found it quite impossible to get satisfactory results from testing the retorted bullion for quicksilver with the means at my disposal. At times there was a very considerable quantity of this metal, especially in bullion received from other mills, rising apparently up to 3 or 4 per cent., and perhaps higher. But on this point I am unable to speak with satisfaction to myself.

*Preliminary Calcining.*—The bullion in lumps from the retorts was thrown into the hot roasting furnace after a regular day's work therein, and left until the next morning. This was done for two reasons—primarily to facilitate the subsequent crushing, and subor-

dinately to drive off any contained quicksilver, a thing generally unnecessary with our own material, but requisite usually when treating other bullion, in order to protect the roaster. As this entailed no special expense it grew to be the regular practice with all bullion. The hearth could be filled up to the top of the arch.

The base bullion thus treated was oxidized to a very considerable extent. The average gain in weight for each year, 1876 and 1877, happened to be exactly the same, viz., 17.4 per cent.

The white bullion underwent less change. The average gain in weight for 1876 was 2.8 per cent.; for 1877, 2.3 per cent. But there was a certain amount of mechanical effect produced, whereby a greater or less proportion was rendered brittle, so that it could be crushed.

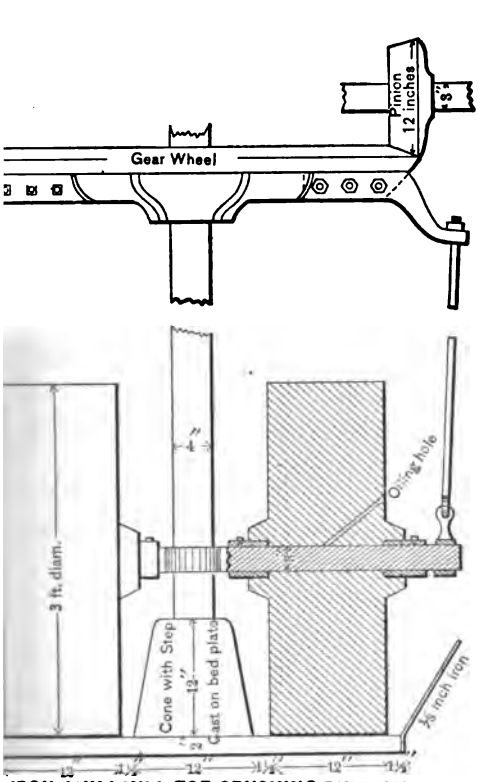
*Crushing.*—All bullion was crushed in a Chili mill, the castings of which were made from the following rough sketch (Fig. 1) given to the foundry. The pan is stationary, the wheels rolling around on it. The power was supplied *gratis* from one of the shafts of the tailings-mill. The Chili mill was run in a small room, the floor of which was covered with sheet-iron plates, to prevent loss and insure cleanliness. It worked well, and needed no repairs or special attention. One man (Chinaman) did the crushing, sifting the pulverized material by hand through a No. 20 wire-screen.

As the mill was run very irregularly it is impossible to state its crushing capacity in exact terms. In my accounts I charged one-half shift for any work not exceeding this length of time (5 hours). According to these accounts the mill crushed about 100 pounds of sulphurized white, and 200 pounds of calcined base bullion (including sifting) per hour. Letting these figures stand (although the time charged was largely in excess), as including all items, the cost of crushing, reduced to terms of retort-material, was 0.175 cents per pound for white bullion, and 0.088 cents per pound for base. The average would be (at 1 part white to 4 parts base) 0.105 cents per pound of retorted bullion.

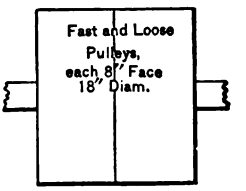
The base bullion crushed almost completely, the average percentage of lumps left during 2 years being 0.55 per cent. The amount of lumps from crushing the (sulphurized) white bullion varied very considerably according to the manner of firing the sulphurizing kettle, and also according to the percentage of melted bars (from the crude-bullion assays, etc.) put in the kettle. The average for 2 years was 6.86 per cent.

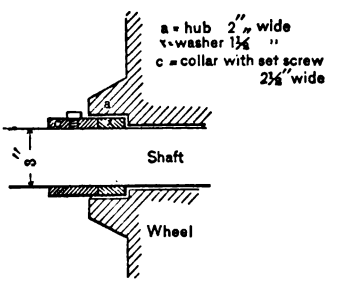
The wear of the mill was very small. The returns from 138,634½

pounds charged to the mill were 138,732 pounds, showing an apparent gain of 97¾ pounds (0.07 per cent.), which probably represents the wear of the wheels and pan.




IRON CHILI MILL FOR CRUSHING BULLION.




ARRANGEMENT TO KEEP DUST FROM JOURNALS

*Roasting Furnace.*—The roasting furnace was a small reverberatory used only for bullion. Its construction is shown in Figs. 2 and 3. The hearth (see also Fig. 4) was composed of 2 cast-iron plates bolted together and bedded in sand. The furnace-walls were recessed on all sides for the plates, as indicated in the drawing. This construction allowed the expansion and contraction of the hearth, and prevented the charge from spilling over the edges of the plates. Iron plates were used, in order that no bullion should be left on the hearth after a charge had been drawn, a matter of importance in making tests and in refining for other companies, some of which, as the "Bonanza firm," were very particular in their requirements. The space between the hearth and the chimney served as a dust-chamber,

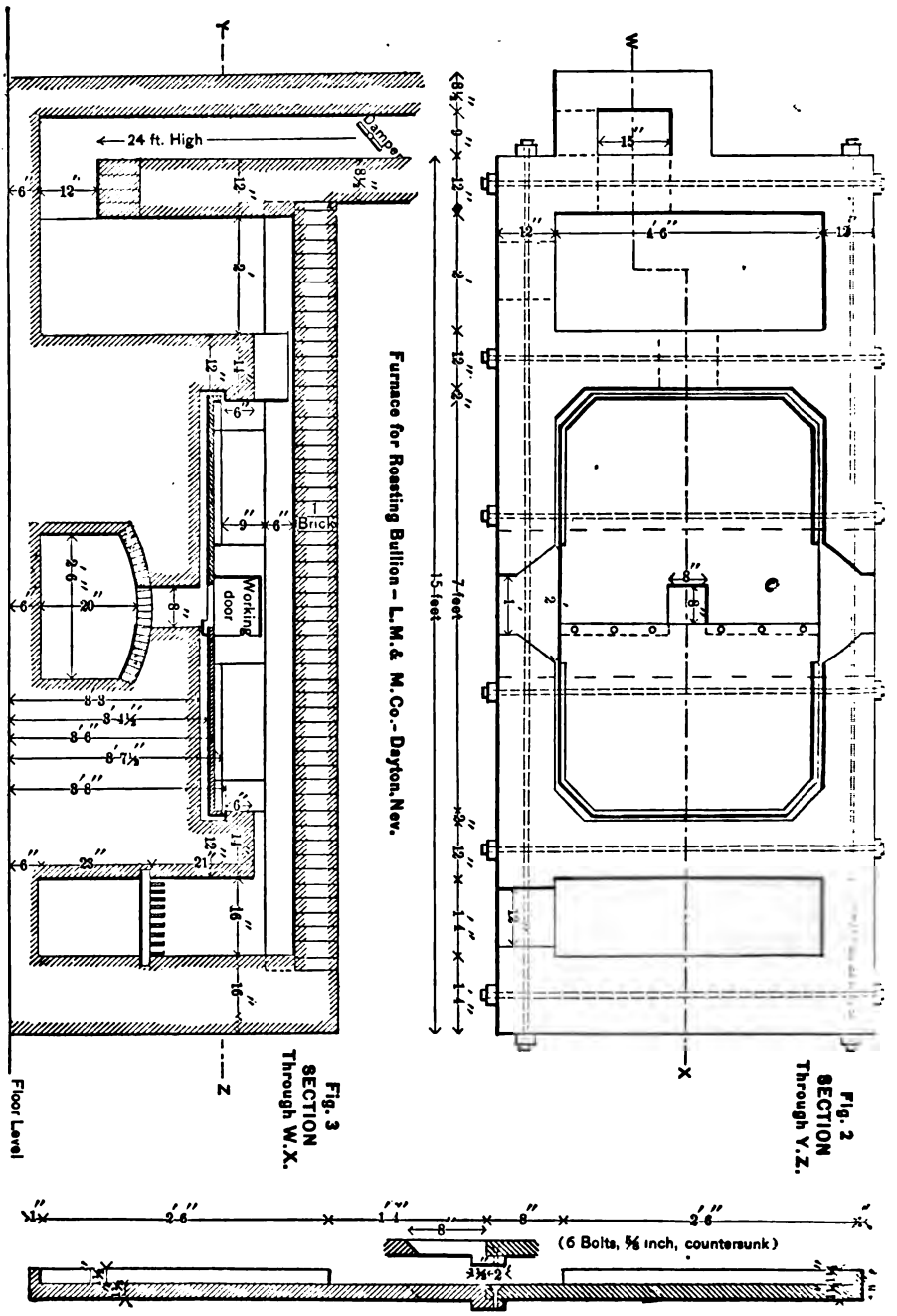



Fig. 4.Enlarged Longitudinal Sections Through HEARTH-PLATES

and proved of ample capacity, the amount of "dust" formed being small.

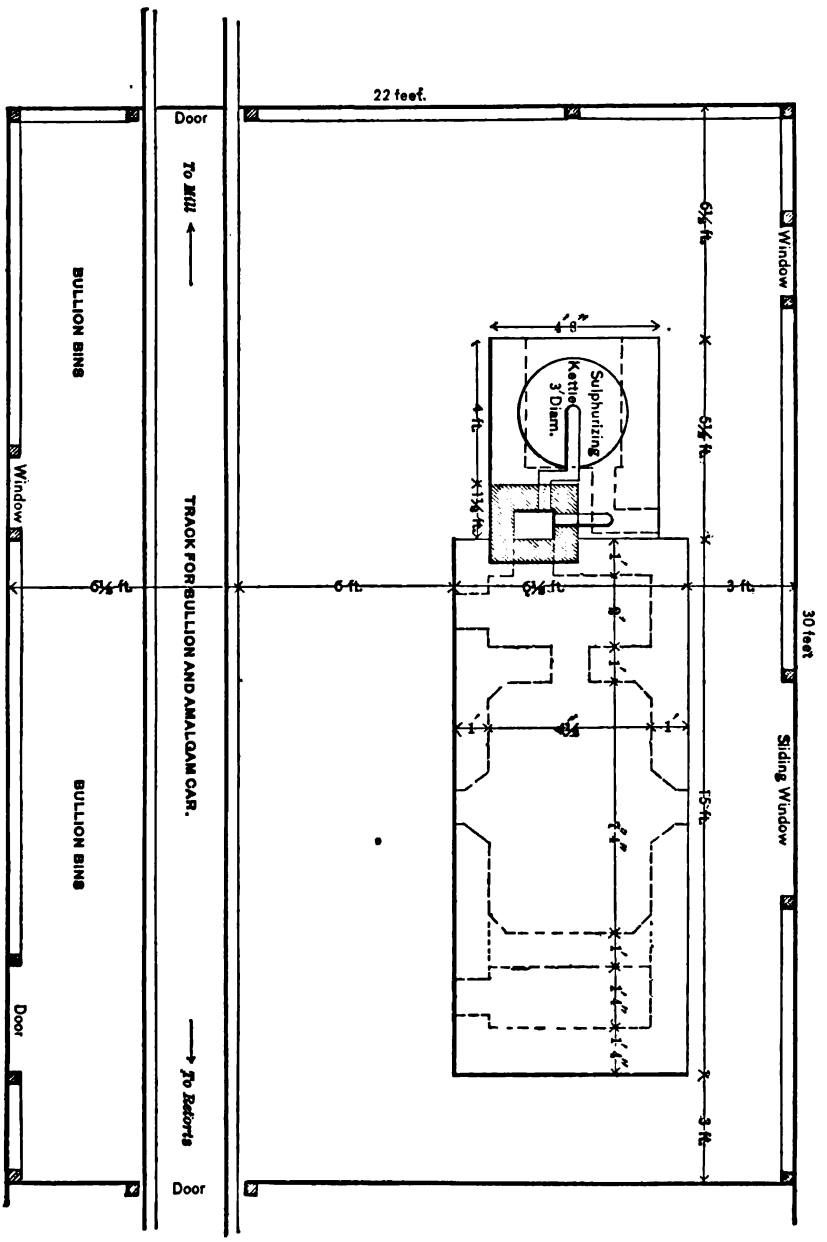



Fig 5. BULLION – FURNACE ROOM – L. M. & M. Co. Dayton, Nev.

Red bricks were used, except for the parts directly exposed to the flame. The mortar for all inside work was a mixture of sand and

clay (materials, by the way, to be had for the hauling), lime being used only for the masonry not affected directly by the fire. The arch was built of one layer of brick set on end and covered with a bed of sand. Air-holes (not shown in the sketch) were originally provided for admitting air through the fire-bridge and the arch to the hearth, and also through the wall into the fireplace, but they seemed to serve no useful purpose, and in time became obliterated. The chimney was 9″x 15″ in section and 24 feet high.

The fireplace for the sulphurizing-kettle was built against the chimney, into which its draft was led. When the kettle was in operation any escaping sulphur fumes were conducted into the chimney by means of an arrangement of hood and pipes of very light sheet-iron, which could be raised or lowered at pleasure.

The furnace-house, Fig. 5, adjoined the retort-house. The floor in front of the furnace and around the sulphurizing-kettle was covered with sheet-iron plates; elsewhere it was of matched boards. A track for the bullion- and amalgam-car ran from the mill through the furnace-room into the retort-house.

The following amounts were paid out for constructing the furnace and the furnace-house (in 1875).

*Cost of Furnace.*

| | | | |
|---|---|---|---|
| *Foundation:* | | | |
| Preparing ground, Chinaman, 1½ shifts, at $1.53, | | $2 30 | |
| Hauling stone, 2-horse team one day, | | 6 25 | |
| Masons, 4 shifts, at $7.50 plus $1.75 fare, | | 31 75 | |
| Masons' helpers, 6½ shifts, at $1.53, | | 9 94 | |
| Lime, 250 pounds, at 2.652 cents, | | 6 63 | |
| | | | $56 87 |
| *Superstructure:* | | | |
| 4980 common brick, at 1.972 cents, | | 98 20 | |
| 400 fire-brick, at 18.85 cents, | | 75 41 | |
| 819 pounds lime, at 2.679 cents, | | 21 94 | |
| Hauling sand and clay, 2-horse team one day, | | 6 25 | |
| Masons, 18½ shifts, at $7.58, | | 140 25 | |
| Masons' helpers, 26 shifts, at $1.53, | | 39 78 | |
| | | | 381 83 |
| *Iron Work:* | | | |
| 2 frames and slip doors, | 160 pounds, | | |
| 1 fire-door, | 155 pounds, | | |
| Hearth plates, | 1695 pounds, | | |
| Hearth-plate discharge cover, | 23 pounds, | | |
| | 2033 lbs., at 8 cents, | 162 64 | |
| Drilling and fitting doors and plates with bolts, | | 18 25 | |
| Patterns for doors, frames, and plates, | | 22 00 | |
| Blacksmithing and old iron, | | 25 00 | |
| | | | 227 89 |
| | | | $666 59 |

*Cost of Furnace Building.*

| | | |
|---|---|---|
| *Lumber:* | | |
| Rough, 4710 feet, at $35 per M, | $164 85 | |
| Dressed, 487 feet, at $65 per M, | 31 66 | |
| Shingles, 6750, at $6.50 per M, | 43 88 | |
| | | $240 39 |
| *Hardware:* | | |
| 1 keg 10-d. nails, | 6 75 | |
| 1 keg 12-d. nails, | 7 00 | |
| 1 gross screws, 1¼ inch, No. 18, | 3 00 | |
| 39 dozen screws, 1¼ inch, No. 13, | 4 88 | |
| 10 sheets iron, ⅛″ x 3′ x 10′, 1708 lbs., at 7.05 cents, | 120 47 | |
| | | 142 10 |
| *Paint:* | | |
| White lead and oil, inside work, | 5 50 | |
| Copper paint, home-made, outside work, not charged, | .... | |
| | | 5 50 |
| *Wages—Carpenters, Painter, and Helpers:* | | |
| 4 shifts at $6.00, | | |
| 1 shift at $4.50, | | |
| 10 shifts at $4.00, | | |
| 12 shifts at $3 50, | | |
| 5 shifts at $3.00, | | |
| — — = 32 shifts, at $3.92, | | 125 50 |
| | | $513 49 |

*Furnace and Building.*

| | | |
|---|---|---|
| Labor, 88½ shifts, at $3.95, | $349 52 = | 29.6 per cent. |
| Material, | 830 56 = | 70.4 per cent. |
| | $1180 08 = | 100.0 per cent. |

*Roasting Base Bullion.*—The usual charge of base bullion for this furnace was 400 pounds, but as much as 500 can be treated easily, while, owing to the way in which the bullion was supplied, the average charge for two years was actually only 384 pounds. Were the furnace running regularly, a normal charge would be about 450 pounds of calcined, corresponding to about 400 pounds of retorted base bullion.

The roasting-process is conducted as usual, the manipulation requiring no special description. The bullion is brought to a bright red heat, stirred well, and moved several times from and towards the fire, so as to expose all parts equally to the heat.

When only one charge was roasted daily, the furnace being nearly or quite cold at the commencement, the operation occupied about 1 shift, or 10 hours. Two charges were roasted in 1½ shift, and 3, or even 4, charges in 24 hours, the last occurring when the furnace was hot at the start. The roaster was able (except in the last case), also,

to sift the charge previously roasted, and to attend to other matters which did not take him away from the furnace building. The roasted material was passed through a No. 10 wire screen, the lumps averaging 1.29 per cent.

The average gain in weight by this operation was 5.4 per cent. of the charge, corresponding to 6½ per cent. of the retorted bullion.

The average gain in weight (2 years), by both calcining and roasting, reduced to terms of retort-bullion, and deducting all lumps, was:

| | |
|---|---|
| By calcining, . . . . . | 17½ per cent. |
| By roasting, . . . . . | 6½ " |
| Total, . . . . . | 24 " |

The oxidation of the last remaining percentage of metallic copper in this material would appear to be, in part, a function of time. Repeated attempts were made to shorten the operation by crushing finer, constant stirring, and the introduction of air through the fire-bridge and the arch and into the fireplace. But no material advantage, in this respect, was ever obtained, the last one or two per cent. of copper oxidizing only very slowly.

One man, per shift, selected carefully for the place, did all the work of roasting.

The fuel was wood; the average amount consumed was 0.271 cord, per shift of 10 hours; or 0.216 cord, per charge (of all kinds) actually roasted. These figures are derived from the work done in eight months in 1877, when 393 charges were treated in 313 shifts with a consumption of 85 measured cords of wood, or, 1 cord to 1493 pounds of retort-bullion.

In 1876 (an unfortunate year, in some respects) 86 cords were charged against the furnace, or, 1 cord to 1040 pounds of retort-bullion. Part of this wood was used elsewhere.

I resist the natural impulse to substitute the figures of 1877 for those of 1876 in the statement of expenses.

Although fuel was dear on the Comstock, it was used most wastefully everywhere. I found the easiest practical way to check this waste was to contract the size of the fireplace to the smallest allowable limits.

*Sulphurizing.*—To this process came the dense material of all kinds—the white bullion, the base lumps, and all the assay-bars.

The sulphurizing-vessel was an old sulphuric-acid parting-kettle of cast-iron, three feet in diameter, provided with a cast-iron cover

which, when the kettle was charged, was luted, and bolted fast to the kettle-flange. The kettle was set in a low brick fireplace of the simplest construction.

The kettle was charged with whatever metal was on hand, as much as 450 pounds being put in; mixed with this was 18 per cent. of sulphur. For the sake, simply, of facilitating the removal of the mass when sulphurized, layers of thin wood (generally old barrel-staves) were placed throughout the charge. The cover was fastened down, and a small fire of chips or any refuse fuel was maintained under the kettle for four or five hours. No particular attention was paid to the length of time of firing (the fuel costing nothing) as the roaster generally charged and fired the kettle during his work on the bullion furnace, and the whole operation of removing the cooled charge and sulphurizing the new one was done in one shift. After the process was finished, the cover was removed and the charge left to cool until the next morning.

The sulphurized material formed a black or grayish-black mass, the lowest part fused, the upper and larger part retaining the general form of the pieces put in, often showing pretty needlelike crystals on the surface. It was removed with hammers and cold chisels—being ductile while warm, but brittle when cold—weighed, and sent to the Chili mill to be crushed. The amount of lumps, after crushing, which would not pass through a No. 20 screen, varied according to the method and length of firing, and the size and density of the pieces charged into the kettle. With only retort-bullion or small base lumps, and a gentle and long-continued fire, the whole charge was sulphurized so completely as to crush in its entirety. On the other hand, owing to the repeated melting of samples for assays and tests, solid bars weighing five and six pounds or more were frequent, and these were sulphurized only after passing several times through the kettle. All lumps from crushing were put in the next kettle.

A small, varying amount of sulphur escaped during the process. On an average, 16.7 lbs. of sulphur combined with 100 lbs. of bullion. The total amount of sulphur used was 21 per cent. of the original weight of the bullion at the Lyon Mill (1876 and 1877), and 20 per cent. at the Omega Mill (1878).

The expense of sulphurizing at Dayton consisted simply of the one item of sulphur, as the labor employed, being so small, was charged for in other work, and any extra fuel possibly used was charged up to roasting.

*Roasting White Bullion.*—A charge was generally about 300

pounds, the actual amount being determined at any one time by the quantity on hand, the furnace having treated as much as 400 pounds.

The sulphurized material roasted quite easily and no special difficulties were encountered in working up to a certain degree of excellence. But it seemed practically impossible to sulphatize all the silver, or to prevent the formation of a very large percentage of lumps. No matter how gently the temperature was raised or how diligently the material was rabbled and pounded, the mass was in the beginning so sticky that about the same proportion of lumps were found at the end of the operation as when the process was conducted more hurriedly.

The fire was increased gradually from the beginning, but the furnace was at no time very hot. For some two hours, the charge was stirred constantly and vigorously, to expose all parts equally to the heat, and to prevent the formation of lumps, or to crush up those already formed as much as possible. About three hours after the roasting had fairly commenced, the first test was made of the condition of the silver. The test consisted simply in putting a small quantity of the hot charge into a porcelain saucer, partially filled with water, and adding a dilute salt-solution. The color of the solution, the appearance of the charge and the relative quantity of silver-chloride formed, show the condition of affairs. The eye is soon trained by experience. The "spangle-reaction," mentioned by Professor Egleston, in his paper on the "Boston and Colorado Smelting Works," * that is, the reduction of the sulphate to bright, glittering spangles of metallic silver by suboxide of copper, was often seen in great beauty.

When the sulphate of copper was almost entirely or even quite decomposed, that is, the test solutions had become nearly or quite colorless, the amount of sulphate of silver (or of chloride in the test) was at its maximum, and the charge was drawn. When the roaster lighted his fire in a cold furnace at 7 A.M., the charge was usually out of the furnace about 2 P.M. If the furnace was warm in the beginning, the time was often reduced materially.

As before mentioned, it seemed impossible to get all the silver into the state of sulphate. The highest proportion ever noted was 75 per cent., while the yearly average attained was about 60 per cent.

The roasting-process was conducted essentially according to the directions given in the text-books, and in its action conformed to the descriptions given. But, at times, a phenomenon was observed

* *Transactions*, vol. iv., p. 288.

which, as far as I have been able to learn, has not been described before in print.

Several times, perhaps a dozen or even more, when, according to the tests, the charge had passed through the condition of maximum sulphatization of the silver, and beyond this, so that the silver sulphate had been decomposed to a large extent, that is, the tests had yielded decreasing amounts of chloride; by continued hot firing, the charge has been brought back to its usual proportion of silver sulphate, that is, the tests have shown an amount of chloride gradually increasing up to the usual point. For instance, when a charge has been ready for drawing at 1 or 2 o'clock P.M., but has remained in the furnace until, say, 4 o'clock, the tests, at this last hour, show very little sulphate; but, by firing strongly and stirring the charge with moderate vigor, the amount is increased, according to the tests, until about 6 o'clock, the average proportion of silver sulphate, so far as the eye can judge, is again reached.

This state of affairs was brought about commonly by some accident; for instance, my detention from the furnace at the time for making tests. But I have also caused it deliberately, although with fear and trembling each time.

Mr. C. A. Stetefeldt has suggested to me a possible explanation of the apparent regeneration of the sulphate of silver in the over-roasted charges. At the Mansfield Works, in Germany, the roasted copper matte in the Ziervogel-process is leached first with pure water and then with water acidified with sulphuric acid. This, it was said, favors the solution of sulphate of silver, a part of which may be present as a *basic* salt insoluble in pure water. While the text-books on chemistry do not record the existence of a basic silver-sulphate, there are indications that such a salt occurs; and it would seem very possible that, in over-roasting the sulphurized bullion at Dayton, the common sulphate was partially decomposed to a basic sulphate, and this, in turn, on continued treatment, was changed back to the ordinary sulphate through the action of the sulphides in the undecomposed lumps, a comparatively small quantity of sulphuric acid being required to effect the regeneration.

The original charge in the furnace consisted, in round figures, of about 500 parts silver, 500 parts copper, and 17 parts sulphur, with very small amounts of gold and of iron. I am not aware of the presence of any other metals.

The roasted bullion was sifted through a No. 8 wire screen. The average amount of lumps in 1876 was 17½ per cent. of the original

charge. I have no notes showing anything as to the percentage of lumps from overworked charges. The highest amount ever recorded was 22.3 per cent. The lumps contained copper oxides, copper and silver sulphates, and copper and silver sulphides principally. By vigorous manipulation, a considerable part could be rubbed through the screen, but this was not permitted.

When possible, the lumps were allowed to accumulate, until amounting to enough for a furnace-charge, when (after crushing) they were roasted by themselves, the operation requiring only two or three hours.

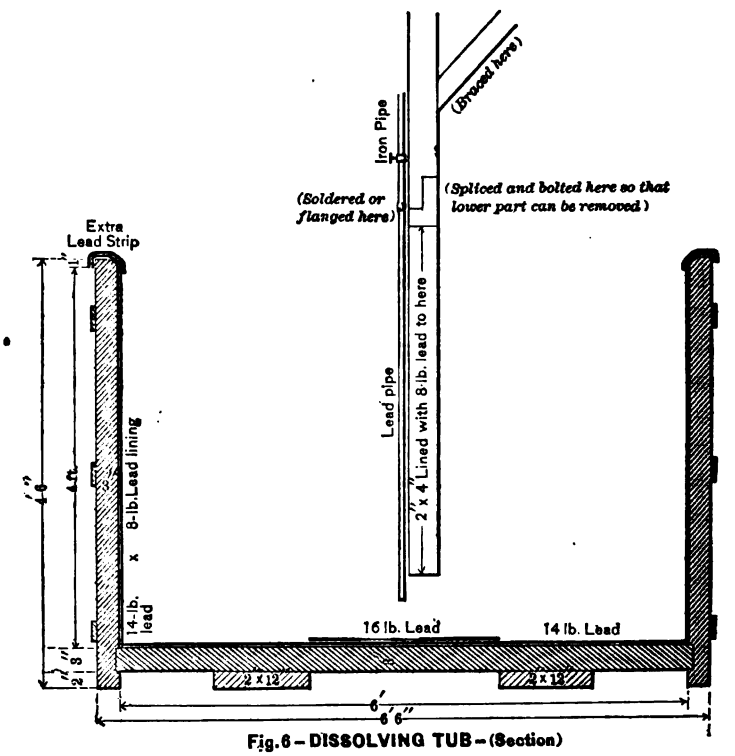



Fig. 6 – DISSOLVING TUB – (Section)

*Dissolving.*—The roasted bullion passed next to the bluestone works, where it was treated with hot dilute sulphuric acid (chamber acid), the base and the white being manipulated separately (as a rule), but in exactly the same manner.

The dissolving-tubs (Fig. 6) are 6 feet in diameter and 4 feet deep, clear dimensions. The sides are composed of 45 staves, 3″ x 6″ x 4′6″ long, dressed to the proper shape, and hooped with 3 iron bands, $\frac{3}{8}$″ thick x $2\frac{1}{4}$″ wide, provided with angle-irons and

bolts for tightening. The bottom planks are 3″ x 12″ lumber, dapped into the sides, with 2 cross-pieces, 2″ x 12″, nailed below them.

The bottom of the tubs and the sides, for a height of 12 inches above the bottom, are lined with 14-pound lead; the rest of the sides with 8-pound lead. Directly under the steam-pipe in the centre of the tub, a piece of 16-pound lead, 2 feet in diameter, is laid on the bottom-lining, and "burned" to it, as a protection, in case the steam-pipe should blow-out. A strip (or strips) of old lead are bent over the upper edges of the sides to protect the lining against the wear of the paddles.

The steam-pipe is of ¾-inch A A lead-pipe, soldered to iron-pipe above the level of the top of the tub. It is closed at its lower end, which reaches within a few inches of the tub-bottom, but has four holes bored in its sides, near the end, so that the steam issues in a horizontal direction, instead of impinging vertically on the lead. The steam-pipe is stiffened by clamping to a central timber, 2″ x 4″, hung from and braced to the ceiling, and lined with 8-pound lead where in contact with the bath. Water- and acid-pipes are provided.

*Cost of Dissolving Tubs.*

| | | | |
|---|---|---|---|
| *Labor*—Carpenter, 4 shifts, at $5.00, . . . | | | |
| Blacksmith, 1 shift, at $5.00, . . . | | | |
| Lead burner, 3 shifts, at $4.50, . . | | | |
| Helper, 3 shifts, at $3.00, . . . | | | |
| 11 shifts at $4.32, . . . . | | $47 50 = | 17 per cent. |
| *Material—Lumber:* | | | |
| Staves, 16 pieces, 3″ x 6″ x 14′, . | | | |
| Bottom, 3 pieces, 3″ x 12″ x 12′, . | | | |
| Cross pieces, 1 piece, 2″ x 12″ x 12′, | | | |
| 478 feet at $35, . . | $16 73 | | |
| *Iron:* | | | |
| 3 hoops, ⅝″ x 2½″ x 21′6″ with angle irons and bolts, 186 pounds, at 12½ cents, . . . . . | 23 25 | | |
| *Lead:* | | | |
| 1 p. 14-lb. lead, 6′ square, bottom, . | | | |
| 1 p. 14-lb. lead, 1′ x 20′, sides, . | | | |
| 1 p. 8-lb. lead, 3½′ x 20′, sides, . | | | |
| 1 p. 8-lb. lead, 1′ x 20′ edges, . . | | | |
| 1504 lbs. at 12 cents, . . | 180 48 | | |
| *Extras*, 5 per cent., . . . . | 12 04 | 232 50 = | 83 per cent. |
| | | $280 00 = | 100 per cent. |

The normal charge was 1200 pounds of base, or 1000 pounds of white bullion; but the common charge was 1000 pounds of base, or

800 pounds of white. The amounts were regulated by the exigencies of each occasion.

The amount of acid used could not be limited to the exact theoretical quantity requisite to form $CuO,SO_3$, although the men on the tubs were kept within certain limits. For instance, in treating 1000 pounds of material, assaying 75 per cent. of copper, theoretically 2083.4 pounds of acid of 45° Beaumé (specific gravity = 1.4493, containing 44.99 per cent. $SO_3$) would be requisite; this corresponded exactly to 11½ inches in depth of the acid tank. In order to be sure of dissolving out all the copper (and iron), and because a moderate excess of acid did no special harm, being utilized afterwards in dissolving ore-charges, and as some metallic silver was always dissolved, the men were allowed to use 1 inch more, or 8.7 per cent. Any amount beyond this limit caused an investigation.

Again, in leaching the charges and in other operations extra acid is necessarily used, at the lowest figures over 10 per cent. Moreover, accidents seem practically unavoidable at times.

The result in practice was that, instead of only 2.8 pounds of 45° acid being used for each pound of metallic copper, an average of nearly 3.7 pounds was purchased by the refinery at Dayton during the year 1876. An unknown proportion of this excess was regained in the other department of the bluestone works, but no allowance was made in the books.

The acid was measured out of a tank whose contents were known. The measuring was by twentieths of an inch. A table was prepared for the men showing how many inches of each degree of strength were necessary for 100 pounds of charges of given percentage in copper.

Two men were employed at each tub.

The tubs were partially filled with the acid needed for a charge, diluted with water to about 20° Beaumé and boiled by live steam. The charge was then fed slowly with a small scoop by one man while his partner vigorously stirred the bath with a wooden paddle, both men paddling from time to time. The chief requisite for good work was to keep the material suspended in the solution until it was substantially free from copper. When the bath reached a strength of over 42° Beaumé, it was weakened with water so long as any more bullion was to be charged. Sufficient steam was used to keep the solution hot. At the end of the process the undissolved residue should be white or grayish-white, and the bath should be from 40° to 42° Beaumé in strength. When the charge was finished, the tub was covered with boards and sacking, to retain the heat, and left

undisturbed for about four hours, or until the charge had settled. The solution was then siphoned into the precipitating tanks.

The bullion remaining in the dissolving-tub was leached once or twice with dilute acid, and then several times with water, being stirred and boiled each time. The leachings, so long as they contained silver, were drawn into the precipitating-tanks. The bullion was put into small lead-lined filtering tubs, 2 feet in diameter and 3 feet high, and washed with hot water until completely free from acid. It was then dried in iron pans and melted in black-lead crucibles. The bars produced averaged, in round numbers, about 950 fine in silver and 17 fine in gold, including all clean-up material which reduced the fineness several points.

*Precipitating Fine Silver.*—The precipitating-tanks were old settlers from the mill, about 10 feet in diameter and 4 feet high. They were lined with lead and furnished with a steam-pipe arranged as for the dissolving-tubs, and were provided with bars of copper laid on the bottom.

The solutions were boiled with steam in these tanks to an extent sufficient to prevent crystallization, and were stirred with wooden paddles occasionally. The silver was precipitated usually in four or five hours; but occasionally trouble was experienced in throwing down the metal completely, and once in a great while the operation was prolonged for twenty or twenty-four hours before the tests with salt solution showed no chloride precipitate. This seemed to occur only when the solution from the tubs contained but a small amount of silver and but little free sulphuric acid. Fortunately extreme cases happened so seldom that the exact cause was never ascertained with certainty. The remedial measures applied were dilution and addition of acid.

The bluestone solution, after being freed from silver, usually had a strength of 36° or 37° B., and after settling was siphoned into crystallizing vats in the cellar. In the extreme exceptional cases above-mentioned, it needed a previous concentration in open lead pans.

The fine-silver precipitate was leached with acid and water, and filtered and washed until free from acid in the same manner as the dissolving-tub residues. All wash-waters were tested for silver.

The washed precipitate was pressed into cakes, dried and melted. The resulting bullion varied in fineness from 994 to 999.5, averaging 997.

In 1876, the refinery (in addition to the bullion treated for other mills) produced from the Lyon company's retort-bullion 121,841

ounces of refined metal, of which 54,854 ounces, or 45 per cent., was in the shape of fine silver, and 66,987 ounces, or 55 per cent., was doré bullion.

The cost of running the bullion into bars was charged to the mill; that of assaying, to the refinery and the bluestone works.

*Crystallizing.*—The crystallizers were wooden vats with flaring sides, and were 7 feet long, 3 feet wide at the top and 2½ feet wide at the bottom, and 2 feet high, clear dimensions. They were constructed of 2-inch plank, braced and strongly nailed. The ends were dapped into the sides, which were bolted together with 4 rods. They were lined with 6-pound lead, one piece $7' \times 7'$ forming the sides and bottom, while one-half of another sheet $3\frac{1}{2}' \times 5'$ formed each end. Considerable economy in lead can be effected by cutting the sheets properly. (See Fig. 7.)

The material (as bought) for a crystallizer consisted of

Lumber, 6 pieces, $2'' \times 12'' \times 16'$, for sides, ends, bottom, bottom-braces, and middle side-braces.
1 piece, $2'' \times 4'' \times 12'$, for end braces.
Lead, as above, 400 pounds.
Iron, 2 bolts, $\frac{1}{2}''$ round iron, 3′ 8″ head to nut.
2 bolts, $\frac{1}{2}''$ round iron, 3′ 2″ head to nut.
5 pounds 12*d.* nails.

The life of such a crystallizer averaged over 3 years of constant use while I was at Dayton.

The crystallizers, after being filled, were covered with boards and sacking for three or four days, in order that the solution might cool off slowly and gradually and thus the formation of larger crystals be promoted. Further than this there was no financial advantage in attempting to obtain fine crystals, for which reason no lead strips were used.

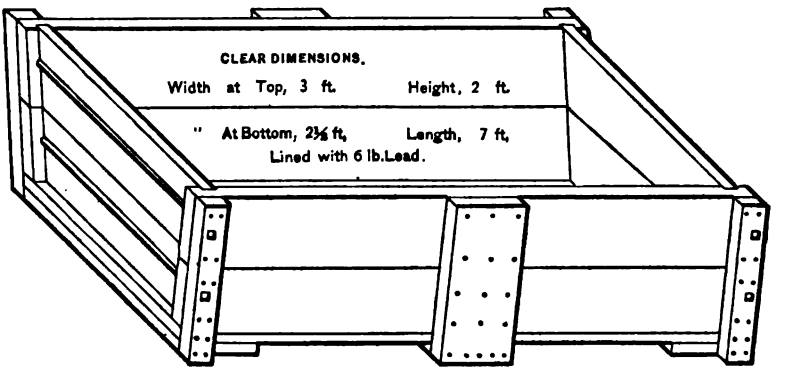
In 6 to 8 days the strength of the liquor in the vats was reduced to 23° to 25° B., when the crystallizers were emptied. The mother-liquor was concentrated and again crystallized, the liquor from this second crystallization being used in dissolving ore charges.

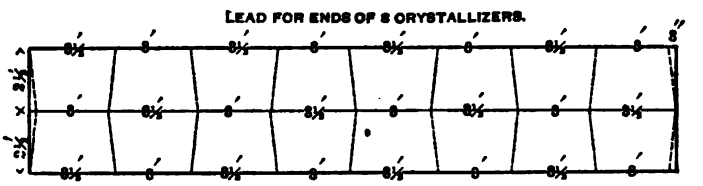
The bluestone, which crystallized on the bottom, sides, and ends of the vats, was taken out, washed, and dried on shelves for several days, and then broken up and packed in barrels for the market. A crystallizer yielded about 1000 pounds of bluestone of excellent quality; often as much as 1200 pounds. Specimens sent to the Nevada State Agricultural Fair, in 1875, received a silver medal—the first prize. The *same* specimens were forwarded by the man-

agers of the Fair (without the knowledge of the company) the next year to the Centennial Exhibition at Philadelphia, and, as part of an exhibit, received favorable mention.*

Too great an excess of acid in the solutions retarded the process of crystallization, increased the proportion of bluestone of too inferior appearance to put on the market, and gave a greater strength of mother-liquor remaining after crystallization.

Fig. 7. BLUESTONE CRYSTALLIZERS, L. M. & M. Co.




*Treatment of Residues.*—These consist of leachings and wash-waters, freed from silver, but containing sulphate of copper in solution; and of concentrated mother-liquor from the crystallizers.

The former, if above 15° B. (the financial limit at Dayton, as determined by experience) were concentrated. Otherwise they were run (much diluted) through a series of vats (old crystallizers arranged so as to overflow from one into another) which contained scrap wrought-iron. The copper thus obtained was washed, dried, and melted into bars for use in the silver-precipitating tanks. As the

* It was a trade secret that nearly all of the "imported English bluestone" in the Comstock market, which commanded at least two cents per pound higher price than the best home-made article, was manufactured at Dayton.

leachings from all the bluestone works was run into these vats, sufficient copper was obtained to supply the wants of the refinery.

The mother-liquor left after crystallizing concentrated solutions contained an excess of free acid, and was used in dissolving copper ore in the bluestone works. No credit was given in the accounts to the refinery for this material.

*Cost of Refining.*—The following figures are for the year 1876, when prices were very high.

Sheet-lead cost (delivered) a small fraction over 12 cents per pound.

The refinery was charged, at the rate of 15 cents per pound, for the copper contained in the "base bullion" produced by the mill of the Lyon Company. The copper in the "white bullion" and in the bullion received from other companies was taken as payment for refining, outside companies being bound, in addition, to purchase at prevailing market rates a fixed amount of bluestone for each hundred pounds of bullion refined for them.

The price charged for acid was unusually high, owing to expensive repairs and construction at the acid chambers, which items were always included in the running expenses.

The refinery, which was in operation only a part of the time, conformed in its work to the requirements of the mill and the bluestone works.

The rate of wages, per shift of 10 hours, was as follows: Masons, $7.50; carpenters, $5.00 and $6.00; blacksmith and mechanic, $5.00 each; lead-burner, who was permanently engaged, worked wherever he was needed, and was, in fact, foreman of the chemical department, $4.50; head men on crystallizers and dissolving tubs, $4.00; watchmen and outside men, $3.00; Chinamen, $1.53; all others, $3.50.

The refinery treated 89,394 pounds of retorted bullion (part of which was received from other mills), and produced 285,224 pounds of crystallized bluestone, and, also, on special order from purchasers, solution containing the equivalent of 16,400 pounds of crystals. From 1 pound of copper about 3.6 pounds of $CuO,SO_3 + 5HO$ were obtained.

The following statement is *not an estimate*, but a record taken from the books of the expenses actually incurred. It should be remarked that, in figuring the cost per pound of making bluestone, the items of *roasting*, *dissolving*, and *concentrating* are divided by 301,624, the total number of pounds of $CuO,SO_3 + 5HO$ and its equivalent manufactured; the other items by 285,224, the number of pounds produced in the shape of crystals.

Under *dissolving* are included all expenses of handling the bullion after roasting; also the cost of making steam.

The figure given for *repair-material* is the net amount after deducting old material (pig lead, etc.) sold; that for *repair-wages* is the sum remaining after charging, so far as possible, to each of the other items, the amounts belonging to it. Thus, a very large proportion under *crystallizing* is for repairs. The wages of the lead-burner, who was permanently employed, are divided according to his work, among all the items except that of *general*.

The bluestone establishment, it should be noted, had been running for years, and most of the plant was well worn.

The item of *general* includes superintendence, office expenses, watchmen, insurance, taxes, interest, and freight on material delivered.

*Cost of Refining* 89,394 *lbs. Retorted Bullion.*

| | | | | Per cent. | Per pound bullion. | Per pound bluestone. |
|---|---|---|---|---|---|---|
| | | | | | Cents. | Cents. |
| Roasting, crushing and sulphurizing | Wages, 525 shifts @ $3.10 | $1629.96 | | | | |
| | Fuel, 86 cords @ $7.85 | 676.14 | | | | |
| | Sulphur | 60.94 | | | | |
| | | | $2367.04 | 15.1 | 2.65 | 0.79 |
| Dissolving | Wages, 586 shifts @ $3.70 | $2166.50 | | | | |
| | Fuel, 240 cords @ $7.85 | 1883.63 | | | | |
| | Acid, 302,053 lbs. @ 1.33 cts. | 4038.15 | | | | |
| | | | 8088.28 | 51.7 | 9.05 | 2.68 |
| Concentrating | Wages, 27½ shifts @ $3.50 | $96.25 | | | | |
| | Fuel, 77 cords @ $7.85 | 604.62 | | | | |
| | | | 700.87 | 4.5 | 0.78 | 0.23 |
| Crystallizing and packing | Wages, 160 shifts @ $3.58 | | 572.09 | 3.7 | 0.64 | 0.20 |
| Cooperage | Wages, 76 shifts @ $3.61 | $275.03 | | | | |
| | Material | 115.20 | | | | |
| | | | 390.23 | 2.5 | 0.43 | 0.14 |
| Repairs | Wages, 76½ shifts @ $4.17 | $319.65 | | | | |
| | Material | 243.22 | | | | |
| | | | 562.87 | 3.6 | 0.63 | 0.20 |
| General | | | 2951.19 | 18.9 | 3.30 | 1.03 |
| Total manufacturing cost | | | $15,632.57 | 100.0 | 17.48 | 5.27 |
| Copper, 48,039 lbs., paid for @ 15 cents. | | | 7,205.85 | | 8.06 | 2.38 |
| Total amounts charged | | | $22,838.42 | | 25.54 | 7.65 |
| Wages, 1451 shifts @ $3.49 | | | $5059.48 | 32.4 | 5.66 | 1.70 |
| Material | | | 7621.90 | 48.7 | 8.52 | 2.54 |
| General | | | 2951.19 | 18.9 | 3.30 | 1.03 |
| | | | $15,632.57 | 100.0 | 17.48 | 5.27 |

Of the total cost, including copper, ($22,838.42); wages constituted 22 per cent.; material, 65 per cent.; general, 13 per cent.

*Omega Mill Refinery.*—After repeated tests of refining methods, including a year's trial at Dayton, the Bonanza firm adopted this process, and built a refinery (Fig. 8) at the Omega Mill, near Virginia City, where was treated all of the base bullion produced by

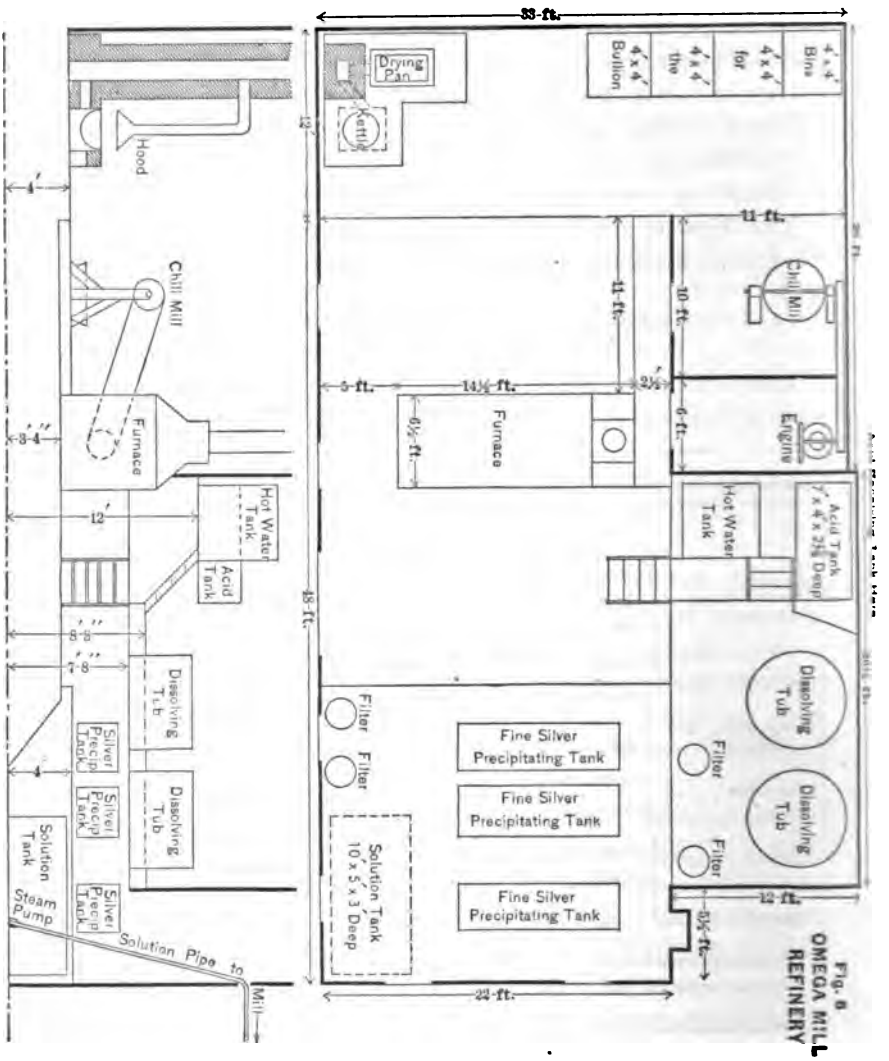



Fig. 8 OMEGA MILL REFINERY

the mills owned by the Pacific Milling Company. I have no statistics of this refinery, but have been informed by the manager, that the financial results obtained were beyond their most sanguine expectations.

Other mills on the Comstock have since made use of this process.

At the Omega refinery the bluestone was not crystallized,* but the sulphate of copper solutions were weakened to 20° B., and run into a stock tank, whence they were pumped by means of a lead injector (called, locally, a "steam pump") to the mill for use in the

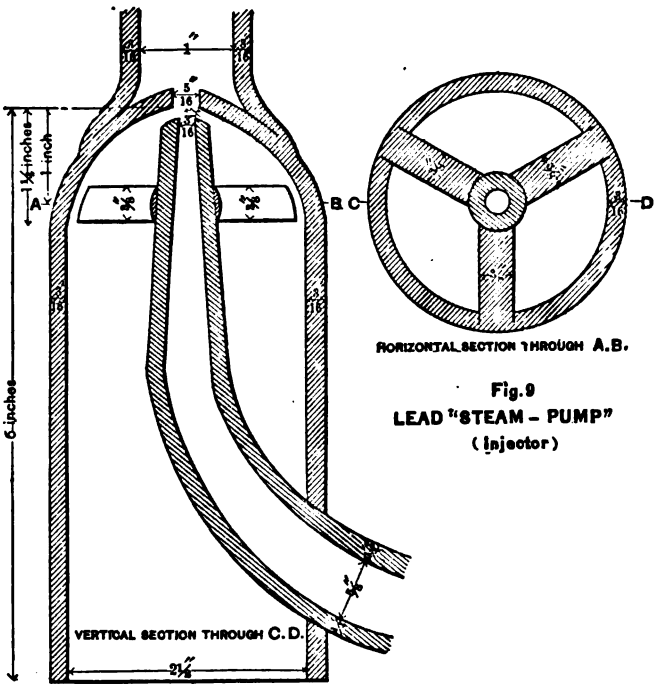



Fig. 9
LEAD "STEAM - PUMP"
(Injector)

amalgamating pans. Steam was furnished to the refinery from the mill boiler. The "steam pump" used (Fig. 9) was devised by my former lead-burner, J. L. Robertson, and was very simple, durable, and effective.

---

## *NOTE ON A DEPOSIT OF FIRE SAND IN CLINTON COUNTY, N. Y.*

BY ALFRED F. BRAINERD, M.E., BIRMINGHAM, ALA.

A PURE white sand, in a large deposit, favorably located with regard to water and railroad transportation, is very desirable for metallurgical and manufacturing purposes. Such a deposit occurs

* I understand that later the solutions were crystallized.

in Clinton County, N. Y., near Mooer's Forks, about 2 miles from the railroad station on the Odgensburg and Lake Champlain Railroad. This bed of sand is located near quite a large stream of water, and covers a tract of some ten acres, with an average depth of about 10 feet. It is mined by an open cut, run in near the stream of water. No "stripping" is required. Underlying the sand is a bed of sandstone of unknown thickness, which Dr. T. Sterry Hunt has pronounced to be the Potsdam sandstone.

This sand has been shipped in large quantities by the present owner, Mr. Aldis O. Brainerd, of St. Albans, Vt., to the St. Albans Iron and Steel Works (now abandoned), to cover the bottom of a 10-ton open-hearth furnace, for which purpose it seemed admirably adapted. It was also used for similar purposes, for a number of years, in the heating furnaces connected with the same works.

A number of car-loads were shipped to a pottery in St. John's, near Montreal, Canada, and used in the manufacture of all kinds of crockery of a superior grade.

A small quantity of the sand was taken and mixed with fluxes in the following proportions to produce glass:

| | Per cent. |
|---|---|
| Sand, | 61.75 |
| Crude potassic carbonate, | 21.85 |
| Chalk, | 14.84 |
| Crude potassic nitrate, | 1.56 |
| | 100.00 |

The whole was thoroughly mixed in a mortar, charged into a large Hessian or sand crucible, placed in a heating furnace at the rolling-mill, and left at a high temperature for two hours; then taken out and allowed to cool, when the crucible was broken, and the resulting glass examined. It was perfectly fused and colorless.

Of the following analyses, here submitted for the purposes of comparison, Nos. I., II., and III. were made by Mr. A. A. Blair, and have never before been published. No. IV. is taken from A. S. McCreath's report, vol. MM of the second Geological Survey of Pennsylvania, page 370. The bed of Oriskany glass sand to which it refers, is described in vol. F of the Survey, pp. 78, 79, 80.

## I.

*Sand from Mooer's Forks, N. Y.*

| | Per cent. |
|---|---|
| Silica, | 98.88 |
| Peroxide of iron, | 0.14 |
| Alumina, | 0.59 |
| Lime, | none |
| Magnesia, | 0.05 |
| Loss by ignition, | 0.26 |
| | 99.92 |

## II.

*Sand from New Jersey.*

| | |
|---|---|
| Silica, | 95.83 |
| Peroxide of iron, | 0.82 |
| Alumina, | 2.46 |
| Lime, | 0.07 |
| Magnesia, | 0.05 |
| Loss by ignition, | 0.74 |
| | 99.97 |

## III.

*Sand from Berkshire, Mass.*

| | |
|---|---|
| Silica, | 98.77 |
| Peroxide of iron, | 0.24 |
| Alumina, | 0.67 |
| Lime, | none |
| Magnesia, | 0.06 |
| Loss by ignition, | 0.20 |
| | 99.94 |

## IV.

*Juniata Sand Company, Mifflin County, Pa.*

| | |
|---|---|
| Silica, | 98.84 |
| Alumina, | 0.17 |
| Oxide of iron, | 0.34 |
| Oxide of manganese, | trace |
| Lime, | trace |
| Magnesia, | trace |
| Loss by ignition, | 0.23 |
| | 99.58 |

It appears from these analyses that the sand from Mooer's Forks, N. Y., compares favorably with others of recognized good quality.

## *THE SAMPLING OF CAST-IRON BORINGS.*

BY PORTER W. SHIMER, M.E., EASTON, PA.

As is well known, cast-iron borings are a mixture of small particles of iron with more or less of finely divided graphite, separated from the surfaces of these small particles during the process of boring. The amount of graphite thus mechanically mixed is, in all cases, quite large enough to cause serious difficulty when the problem is to obtain an average sample of a given lot of borings for carbon determination. This difficulty arises from the necessity of obtaining a uniform mixture of the heavy and comparatively coarse borings with the finely divided and light graphite, and of removing a sample for analysis without disturbing the uniformity of this mixture.

It was first sought to overcome this difficulty by having the borings made very fine, so that they might have more nearly the size of the particles of graphite. It was not practicable, however, to secure this uniformity of size, since much of the graphite is in the form of the finest dust. At all events, the duplicate determinations of carbon in these fine borings, made with every precaution by combustion in oxygen, frequently showed differences too large to be accounted for in any other way than by imperfect sampling.

Very coarse borings were also tried with the idea that the graphite separated from these large and heavy pieces would perhaps be inappreciable; but it was found that quite enough was separated to vitiate the results.

Various methods of mixing were tried, both in the bottle and on glazed paper; but in all these mixtures it was found that duplicate samples seldom contained the same proportion of the mechanically mixed graphite; and when they did, there could be no certainty that it was the true proportion. All this was shown many times over by the failure of duplicates to agree closely, the difference being sometimes so much as 0.20 per cent. It was finally clear that nothing was to be hoped from these methods. Even if we could secure a perfect mixture containing in every part its due proportion of graphite, it would run a great risk of being destroyed the moment a spatula was inserted to remove a sample: for the least agitation causes some of the graphite to fall through between the coarser borings.

The sampling difficulty was finally overcome in the following way: The borings are carefully poured out into a large porcelain crucible or dish, and enough alcohol is added to merely moisten them (2 c.c. alcohol to 30 grams borings). Mix thoroughly for about five minutes. Remove with a spatula as many samples of the moist borings as are needed, weighing them out roughly so as to get approximately the weights desired. Dry off the alcohol and weigh accurately. The samples thus obtained perfectly represent the average of the original sample, for the alcohol simply serves temporarily to hold the graphite where it belongs, upon the surface of the borings.

As the alcohol evaporates from the original sample the graphite again falls away from the borings, and the moistening must be repeated when new samples are to be removed.

It is not at all difficult to obtain alcohol sufficiently pure for this purpose. An estimation, based on a determination of the carbonaceous residue left on evaporation, showed that the alcohol used in these experiments would cause an error which would not appear until the fifth decimal place in the percentage of carbon. I have made many duplicate carbon determinations since using the moist sampling method, and have had none but satisfactory results, having never found a greater difference than .03 per cent. between duplicates. Generally the difference is from .01 to .02 only.

The following total carbon results show the improvement:

| | I. | II. | |
|---|---|---|---|
| Mixed dry in the bottle, . . . . | 3.68 | 3.84 | per cent. |
| Moistened with alcohol and mixed, . . | 3.97 | 3.99 | " |

The first results are an extreme case of unsatisfactory duplicates; and they also show the tendency of the graphite to go to the bottom of the bottle when mixed dry. The mechanically mixed graphite, approximately determined by removing the iron by means of a magnet from samples taken moist, was 0.76 and 0.79 per cent. in duplicate determinations.

After shaking up the dry borings a few times, and removing nearly all from the bottle, the remaining sample contained 1.29 per cent mechanically mixed graphite.

The other determinations, such as phosphorus and silicon (iron excepted), are, perhaps, not appreciably affected when samples are taken dry. But whenever samples are thus taken, the borings which remain are forever vitiated for carbon determinations which shall

truthfully represent the original sample. In very careful work, therefore, and especially when there is any prospect of subsequent carbon determinations to be made, it is necessary to moisten the borings when weighing out samples for phosphorus and silicon, or to have two sets of borings made, one of which is to be reserved for carbon determinations. For iron determinations the samples should always be taken moist.

It was suggested by Mr. Frank Firmstone, Superintendent of the Glendon Iron Works, to determine whether or not there is any appreciable loss of graphitic dust while making cast-iron turnings according to the method devised by him, in which the turnings are taken equally from the whole section of a piece of pig iron, the outside being first removed. Through the kindness of Mr. Firmstone, I was enabled to procure from the same piece of pig iron a sample of turnings taken dry, a second sample kept moist with alcohol to prevent loss of dust, and several sections $\frac{1}{2}$ inch in thickness.

The following are the total carbon results from these samples:

I. Turnings taken dry, but sampled moist.
II. Turnings taken moist.
III. Thin section.

| I. | II. | III. |
|---|---|---|
| 4.132 | 4.122 | 4.031 |
| 4.123 | 4.123 | 4.038 |
| 4.111 | 4.103 | 4.108 |

The results under I. and II. show that, with care in catching the turnings, and avoidance of drafts of air, there is no appreciable loss of graphitic dust. The first two results on the thin section are low, because of incomplete decomposition of the iron when, after forty hours, hydrochloric acid was added to complete the solution. The third result is about right; but complete decomposition was obtained in this case by frequent and long-continued stirring. While, therefore, it is possible to obtain the correct total carbon by use of a thin section, it offers no advantage in point of time; since borings may be dissolved in neutral and cold copper and ammonium chloride solution in fifteen to twenty minutes by constant stirring.

Some chemists, with a keen appreciation of the sampling difficulty, have proposed to overcome it by using clippings of the iron from $\frac{1}{8}$ to $\frac{1}{10}$ inch in thickness. While it is no doubt possible, in most cases, to obtain the true result by this means, it is open to the

objection of being very slow when these clippings are to be dissolved in neutral copper and ammonium chloride solution. Furthermore, the weight of iron taken for carbon determination in cast iron being limited by convenience to about 3 grams, a very few clippings make up this weight, and these represent only those parts of the sample from which they happen to come. While there may not be an appreciable difference in the composition, or in the condition of the carbon of the different parts of a section of pig iron, it is yet possible that there may be; and in this case it is easy to be on the safe side.

When turnings are taken equally from the whole section of a piece of pig iron, and are then moistened with alcohol and thoroughly mixed, every part of the section has its due representation in a sample of 3 grams.

It may not be out of place to add, that in sampling ores, and, in fact, any similar mixture of particles of different size, composition, and specific gravity, I am now accustomed to moisten with water before mixing. This secures a uniform mixture of coarse and fine parts from which a true sample can easily be removed, prevents loss of dust, and is in every way more satisfactory than mixing dry.

In pulverized ores it is very common for the finest part to consist principally of lighter gangue material; and the problem of securing a true sample of such a mixture is similar to that of obtaining a true sample of a mixture of cast-iron borings and graphite.

---

## *NOTE ON THE DETERMINATION OF SMALL QUANTITIES OF TITANIUM IN IRONS AND STEELS.*

BY HORACE L. WELLS, NEW HAVEN, CONN.

THE gravimetric determination of titanium in irons and steels is extremely difficult. It may be well, therefore, to call the attention of those members of the Institute who are interested in the chemistry of iron to a colorimetric method, which I have slightly elaborated to adapt it to the case under consideration.

Schön * discovered that hydrogen peroxide produces, in certain solutions of titanic acid, a very intense color similar to that of ferric

* Fresenius' *Zeitschrift*, 1870, p. 330.

chloride. He suggested the use of the reaction as a test for hydrogen peroxide. Weller* has used this reaction as the basis of a colorimetric method for determining titanic acid, which he has shown to be very accurate, particularly for small quantities. He did not attempt, however, to apply the method in the presence of much iron, because the color of the iron solution interfered.

I have succeeded in applying the method in the presence of iron, when the amount of the iron is approximately known.

The following are necessary for analysis:

1. A standard solution of $TiO_2$ in $H_2SO_4$. This is best prepared from the salt $K_2TiF_6$.† An accurately weighed quantity of this salt (dried at 100° C.) is treated with a relatively large quantity of strong $H_2SO_4$; the mixture is heated in a platinum vessel until $H_2SO_4$ fumes are copiously evolved, to ensure the complete removal of HF, which interferes with the reaction with $H_2O_2$; the $H_2SO_4$ is cooled and diluted with water (cautiously, to avoid much heating of the solution), until 1 c.c. contains $\frac{1}{10}$ m.g. of Ti. The salt $K_2TiF_6$ contains just one-fifth its weight of Ti, consequently 1 c.c. of this solution should correspond to $\frac{1}{2}$ m.g. of the salt used in its preparation. If a sufficient amount of $H_2SO_4$ has been used, this solution will remain perfectly clear.

2. A solution of ferric sulphate in $H_2SO_4$ containing an approximately known amount of iron. This is made by dissolving a known amount of metallic iron free from Ti, or a known amount of crystallized ferrous sulphate in $HNO_3$ and $H_2SO_4$. Enough $HNO_3$ should be added to completely oxidize the iron to the ferric state, and 10 c.c. of concentrated $H_2SO_4$ should be present for each gram of Fe. The $HNO_3$ is removed by evaporation and the liquid is diluted until 100 c.c. contain 1 gram Fe.

3. A solution of hydrogen peroxide. This can be purchased pure enough for the purpose.

*The Process.*—One gram of the metal to be tested is dissolved in $HNO_3$, 10 c.c. of conc. $H_2SO_4$ are added, the $HNO_3$ is removed by evaporation, the $H_2SO_4$ is strongly heated to ensure the solution of all the Ti; the sulphates are dissolved in a little water with the aid

* *Berichte d. chem. Ges.*, 1882, II. p. 2592.

† This salt can be prepared as follows: Fuse 1 part of rutile, brookite or other nearly pure $TiO_2$ with 2 parts of $K_2CO_3$ in a platinum crucible, until the substance is decomposed. Pulverize the mass, dissolve in dilute HF, and crystallize the salt by cooling the hot solution. The crude salt thus obtained must be purified by repeated crystallization. It can be crystallized in glass vessels after the free HF has been removed.

of heat, the solution is filtered and diluted to 100 c.c. in a small narrow beaker. To a second beaker of the same size and shape enough of the ferric sulphate solution (No. 2) is added to give the same amount of Fe as in the metal analyzed, and this is diluted, if necessary, to 100 c.c. The two beakers now contain practically equal amounts of $Fe_2(SO_4)_3$ and $H_2SO_4$ in equal volumes, and their colors should be identical when placed on a white surface in an even light and looked down upon. About 5 c.c. of $H_2O_2$ are added to the second beaker (the blank), in which it should produce no change of color; then the same amount of $H_2O_2$ is added to the first solution. If this deepens the color, Ti is indicated.* The amount of Ti is determined by adding the standard Ti solution from a burette to the blank until the colors correspond. This reaction is extremely delicate. As little as .0001 g. of Ti will show its presence in the presence of 1 g. of Fe as ferric sulphate. A few experiments made by putting some of the standard Ti solution into one beaker and matching its color in another will convince the operator that the method is accurate for small quantities.

A slight modification of this method can be readily devised to adapt it to the examination of ores in which the amount of $TiO_2$ is small, or in which only approximate results are required. For this purpose a standard Ti solution, about ten times as strong as the one recommended above, would be preferable.

Since bringing this method into use, I have not encountered in my laboratory practice any commercial specimens of metals showing titanium by it, but have operated upon solutions into which a known quantity of titanium had been introduced. This constitutes, however, the best test of the accuracy of the method; and the results thus obtained warrant me in recommending it.

I have frequently made use of $H_2O_2$ as a qualitative reagent for $TiO_2$ in ores. For this purpose no standard solutions are necessary; the whole operation consists in making a sulphuric acid solution of the ore, either by means of a fusion with acid potassium sulphate, or otherwise, and adding to it an excess of $H_2O_2$. The presence of ammonium salts is not allowable, as they decompose $H_2O_2$.

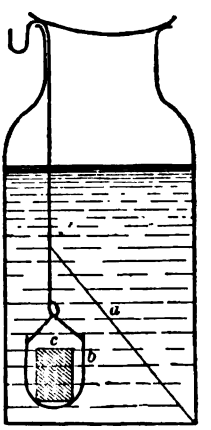
* Chromium, vanadium and molybdenum also form colored compounds with $H_2O_2$ (Weller).

## *NOTE ON THE REDUCTION OF FERRIC SOLUTIONS BY THE USE OF AMALGAMATED ZINC AND PLATINUM FOIL.*

BY ALFRED L. BEEBE, NEW YORK CITY.

In the determination of iron in sulphuric acid solution by titration with potassium permanganate, amalgamated zinc and platinum foil are very generally employed to reduce the iron to the ferrous state. As ordinarily employed, their use for this purpose is frequently attended with two practical difficulties. The first is the amalgamation of the platinum strip through its contact with the zinc, and the consequent cessation of all reducing action. The second is encountered in transferring the solution from the reducing-bottle to the beaker in which the titration is to be made. Unless great care is exercised in this operation the zinc will fall into the beaker, fracturing it, and causing the loss of the analysis.

The following simple modification of the usual method has been found by the writer to obviate entirely the difficulties above referred




Apparatus for Reducing Ferric Solutions.

to. A strip of thin platinum foil, about one inch square, is perforated with pin-holes over its entire surface. It is then bent into the shape of a letter U, and its opposite corners are connected by short pieces of platinum wire, so as to form a sort of basket. In this is placed a piece of amalgamated zinc of convenient size, and the whole is suspended by a stout platinum or silver wire in the bottle containing the solution to be reduced. Another strip of platinum foil,

about $1\frac{1}{2}'' \times 2\frac{1}{2}''$ in size, is then dropped into the bottle, in such a way as to lean against the wire supporting the basket and zinc, without coming into contact with the latter,

Galvanic action at once commences, and hydrogen is evolved in abundance from the surface of the foil, which never becomes amalgamated, as it comes into indirect contact only with the zinc.

When the reduction is complete, the platinum basket containing the zinc is removed from the solution, washed in the titrating beaker and laid aside, all danger of fracturing the beaker being thus avoided.

In the accompanying figure, which shows the arrangement of the apparatus when in use, *a* is the large platinum strip, *b* the basket, and *c* the piece of amalgamated zinc.

---

## *NOTE ON A CUPEL-MACHINE.*

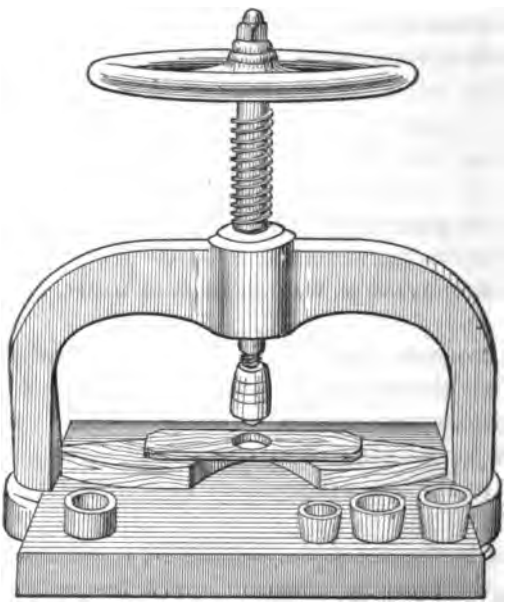
BY PROFESSOR CHARLES E. WAIT, SCHOOL OF MINES, ROLLA, MISSOURI.

In order to secure cupels uniform in size, density, etc., I have arranged a machine which has proved quite satisfactory, and is so simple and inexpensive as to be within the reach of nearly everyone. It has been in operation here about four years, and with it all cupels used in the assay department of the School of Mines have been made.

As shown in the accompanying figure, it consists of a common letter-press, the movable platen of which has been removed. In place of the plate, there is attached to the screw a plunger, which turns with the screw, moving up and down, and making the depression in the cupel. The ring holding the bone-ash is held in place directly underneath the plunger by a wooden guide fastened to the base of the press. There is also fastened to the top of the guide for the ring, at a distance above the base of the press equal to the height of the cupel-ring, a piece of wood about $\frac{3}{8}$ inch thick, under which the ring will just slide into place, and through which there is cut a circular hole exactly fitting the plunger, guiding it in its downward movement always in the same vertical line; this last guide not only directs the plunger, but also prevents the lifting of the ring by the plunger, upon the raising of the latter.

There is also a small spring (not shown in the figure) which is arranged to push forward the ring after the ash has been compressed. As soon as the plunger is raised and the finger removed from the ring, it is pushed forward by this spring several inches, clearing both guides to a position on the front of the base of the press, from which it is taken to a simple contrivance for removing the cupel.

To make a cupel, fill the ring with slightly moistened ash, the plunger being raised just high enough to allow the ring to be put in place with the left hand, holding it with the left thumb. With



Cupel-machine.

the right hand give the wheel to which the screw is attached about one turn, depending upon the pressure required; reverse the wheel until the plunger is raised, and remove the thumb suddenly, at which moment the spring will push the ring to the front.

Cupels of any size may be made by having plunger, ring, and guides to suit. I have been making three sizes: $1\frac{1}{4}$ inch, weighing 18 grams; $1\frac{5}{8}$ inch, weighing 37 grams; and $1\frac{5}{8}$ inch, increased depth, weighing 48 grams.

## *NOTE ON THE USE OF GASOLINE-GAS IN A CHEMICAL LABORATORY.*

BY PROFESSOR CHARLES E. WAIT, SCHOOL OF MINES, ROLLA, MO.

HAVING had some experience in the use of gasoline-gas in a laboratory, I have been induced by frequent inquiry to present a few hints concerning it, which I hope may be of some value to those who are out of the reach of coal-gas, and who contemplate using this gas.

While I will not delay to describe the method by which this gas is made, it may not be out of place to note that, unless frequent charges are put into the carburetter, the gas is variable in richness. This may be partially avoided, it is said, by repeatedly pumping from one cell in the carburetter to another.

If a machine is in constant use for many months without recharging, the gas becomes rather poor for illuminating purposes; but in this condition it may be burned in a Bunsen burner with advantage. Could the gas be used always in this condition, no difficulty would be experienced, and it would be quite satisfactory for general laboratory purposes. Considerable annoyance, however, is experienced whenever the machine is filled with gasoline. The Bunsen and other burners then produce a flame too smoky to be used with comfort, and, in fact, with most of them, a full supply of air, turned on at the base of the burner, will not suffice to completely burn off all the carbon.

Finding it necessary to adopt some method by which I could get a flame free from unconsumed carbon, I adopted a plan which has in every way proved satisfactory.

In addition to the pipe conveying the gas to the table, and arranged with a stopcock, there is brought to the table, within a few inches of the gas-pipe, another pipe, conveying air direct from the pump. This pipe is also arranged with a stop-cock. The air- and gas-pipes are now connected with one pipe by a T joint; and to this last pipe is attached, by rubber tubing, the Bunsen or other burner.

I have successfully used this simple system in connection with both small and large Bunsen burners, a burner with three tubes, and a Fletcher burner; and recently I have added a new still to our equipment, and have been using with it a Fletcher special high-power burner No. 6, to which this system has been applied. With

a combustion-furnace having fifteen burners, I have found the use of the air as above described satisfactory.

Bunsen burners may be altered to burn this gas, and, after some practice, I have been able to secure the desired results; but, for the production of both small and large flames, with and without the rose, I have found the use of air as above described about all that could be desired.

I have just received a new burner which was made for general laboratory use, designed to burn this gas, and sent to me for trial; but have not yet given it a sufficient test to enable me to speak concerning its merits.

---

## *A NEW METHOD OF LAYING SUBMARINE TUNNELS AND TUBES.*

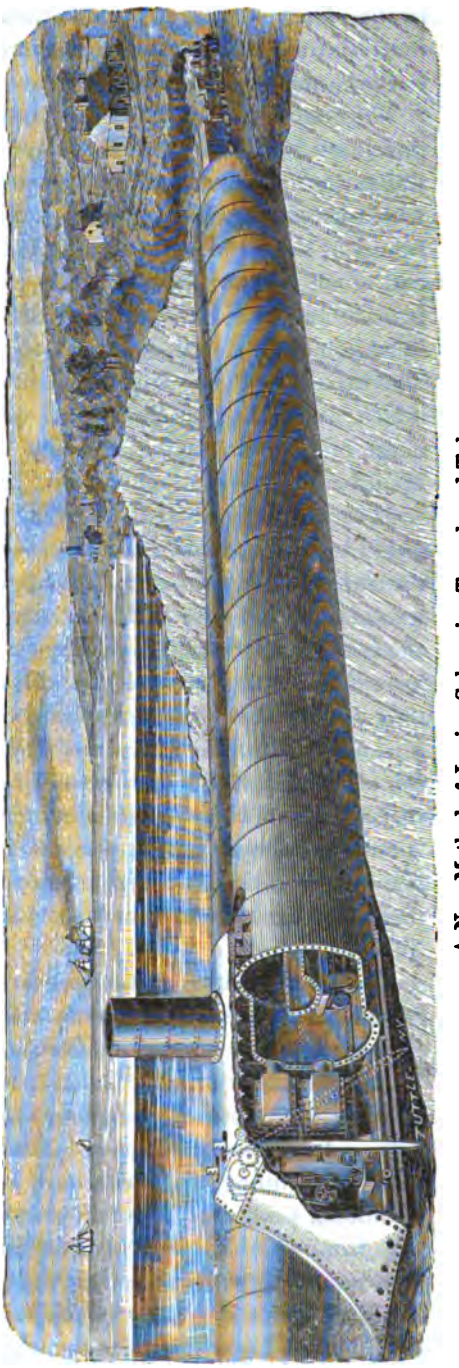
BY RICHARD P. ROTHWELL, NEW YORK CITY.

THE device to which I desire to call the attention of the members of the Institute consists of a water-tight caisson, which is connected by a stuffing-box with the tube to be laid, and the caisson is pushed forward with hydraulic jacks set against the end of the tube. The tube is of hard white iron, cast in chills in segments. These segments are carried from shore through the tube itself, in which a track is laid as the work progresses, and the segments are bolted together in the caisson, where there is ample room to work and proper appliances for handling heavy weights. As each segment is bolted on, the jacks are set against its forward end, and when the whole ring is complete, the caisson is pushed forward by the jacks, a trench having been dredged out in front of it, or, in very loose ground, jets of water under a heavy pressure can be thrown out to loosen the ground in front of the caisson. The direction in which the caisson is pushed is completely under control, and both the caisson and the tube are loaded to the amount necessary to overcome their buoyancy.

I understand that Mr. H. H. Hall, of New York, the inventor, is negotiating for the construction of a 16-foot tunnel of this kind across the Straits of Northumberland, between Prince Edward Island and the main-land, and for tunnels in several other places. One of the most interesting uses of this system is in laying water mains out into lakes. The work can be carried on without inter-

FIG. 1.

FIG. 2.



A New Method of Laying Submarine Tunnels and Tubes.

ruption from storms, etc.; and when the desired distance has been reached, the caisson can be converted into a filter, which can be easily cleaned from time to time.

The accompanying illustrations show the general design of this novel and ingenious method of laying tubes, both for railroad and water-work purposes. Without entering into details of construction, which necessarily vary with the local conditions, it is evident that a tunnel of this kind could in most cases be laid at a small part of the cost of an ordinary tunnel. The iron segments may be cast at the furnace, and would, therefore, cost little more than pig-iron, and the operation of putting the segments together is simple and inexpensive. The tube would generally be lined with a concrete or beton lining, which would help to load it and would protect the iron from the effect of corroding gases. White cast-iron is very slightly acted upon by sea-water.

My own professional interest in this improvement was first engaged by the fact that I had devised a somewhat similar contrivance for sinking a shaft in Pennsylvania about fifteen years ago. I used a solid sinking-frame of 12-inch timbers, with a bevel iron shoe on the bottom, and into this sinking-frame a number of hydraulic jacks were let, so that when the ram was down the head of the jack rose only a little above the top of the frame. The sinking-frame was pushed down, as the gravel and clay were removed, by jacking from the permanent lining of the shaft, which was also composed of 12-inch timbers. Heavy plate-iron bolted to the outside of the sinking-frame lapped over at least two timbers of the permanent lining, and being pressed tightly against these, prevented the gravel, sand, etc., from entering the shaft between the sinking-frame and the shaft-lining.

This method of sinking was found extremely convenient; the movement of the sinking-frame was under perfect control, and the parties who used it found no drawback to it, though the frame was 75 feet long over all and 12 or 13 feet wide, the shaft being intended to have four hoistways, a pumpway, and a manway. When the sinking-frame had been pushed a sufficient distance down from the permanent lining, the jacks were lowered, a few at a time, and an additional timber of the lining was slipped in and formed a new base from which to push with the jacks.

From the experience in that case, as well as from the simplicity of the problem, it appears to me possible to apply this new method of tunnel-laying without serious difficulty, and with great economy

where the local conditions are favorable. And there are many cases where the question of grade, the nature of the bottom, and other conditions render the construction of a tunnel in the ordinary way impracticable or enormously expensive. This new system offers such striking advantages in such cases, as well as for laying water-pipes out into lakes, that it cannot fail to interest engineers, and in that expectation I have brought it before the Institute at this time.

---

## *MITIS-CASTINGS FROM WROUGHT-IRON OR STEEL.*

BY PETTER ÖSTBERG, STOCKHOLM, SWEDEN.

HAVING brought with me to this meeting a couple of "Mitis" wrought-iron castings, I have found that they attracted a great deal of attention from steel manufacturers, and especially from those experienced in making castings, among whom some have said that they felt inclined to "*unhesitatingly declare their manufacture an impossibility*," if they had not seen the samples. The consequent demand for explanation of the method of manufacture has been so great that I accept with pleasure the request by the President to address the meeting on the subject.

My object in this address shall be only to explain the main features of the manufacture, referring those who take more interest in the matter to Mr. Th. Nordenfelt's paper, read before the British Iron and Steel Institute, reprinted in many American papers, and containing both a historical sketch of the inventions and many interesting details.

As the manufacture of castings from steel by others is, at least to some extent, a success, I shall, in my explanations hereafter, refer to wrought-iron, although our mode of manufacture is equally applicable, with corresponding advantage, to steel of any temper.

The successful manufacture of castings depends upon several very important matters, besides the necessary skill of the workman. You must have a suitable metal as raw material; you must have an efficient and suitable furnace for smelting, so as not to injure the metal; you must be able to handle the metal in a suitable way, from the time it is ready in the furnace until it is poured into the moulds; you must have a suitable moulding material. I claim that in every one of these different branches we have made great

improvements—essential to the successful manufacture of castings from wrought iron or low-grade steel.

1. *The Moulding Material.*—The principal properties of a moulding material are, that it shall be fire-proof enough for the temperature of the molten metal to be run into the mould, so that it does not fuse and stick to the casting, leaving a poor and coarse surface; and that it shall not give out any gases or have a hardening influence upon the casting. We have a patented moulding material (United States Patent, No. 317,062), which is perfectly fire-proof at the temperature of molten wrought iron, and is excellent in every respect. This material is made from pure and good fire-clay *alone*, hard burnt, finely ground, and mixed with sugar or molasses as binding material, which does not, like clay-water, impair the infusibility. The sand made from silica bricks, which is extensively used in this country, does not approach our material in quality, as you will see by comparing the surface of these castings with any others made even from hard steel.

2. *The Melting of the Metal.*—Wrought iron requires a temperature of about 4000° for melting; and I think I am not far wrong in saying that prior to our doing it no one had practically succeeded in melting wrought iron. Where wrought iron has been melted in crucibles it cannot be said to have been a practical success, considering the time required and the waste of fuel and crucibles, etc. I do not mean to say that our mode of melting is the only way to obtain the requisite heat; but I will say, that I do not know of any other way, in which you can obtain the result in a sufficiently convenient and practical way to make it a success. As yet we use at the small foundry in Worcester, where these castings are made, as well as at the Mitis foundries in Europe, only crucible furnaces. As this furnace (Patent No. 321,840, and another patent to be issued next month) is quite remarkable for its simplicity, efficiency, easy control, regularity in working, convenience and cheapness, I will give a short description. The furnace, in which petroleum is used for fuel, is constructed upon the same principle as a common petroleum lamp. We all know how important it is for a lamp that the area of the air inlet-holes below the burner should have the right proportion to the area of the funnel; and supposing these things are in the right proportion for the maximum efficiency of the particular oil used, we all know how to obtain this maximum efficiency; simply by turning the wick higher, until the lamp is on the point of smoking. But in turning the wick higher or lower, what is it

we do? We expose a different area of the wick, and thereby a different area of the oil to the flame. If the wick is not turned sufficiently high, more air than necessary passes through and the full efficiency is not obtained. If the wick is turned too high, the lamp smokes from want of air. And although it has thus for years been the easiest thing in the world for any one of us to burn liquid fuel in a lamp without smoke (complete combustion) and with maximum efficiency, the same long-searched-for result in furnaces was accomplished only a couple of years ago by Mr. L. Nobel, of St. Petersburg, with the assistance of Mr. C. Wittenstrom, of Stockholm. Instead of, as in the lamp, changing the area of oil exposed to the flame, we keep a constant surface of oil exposed, having the area of the chimney in proportion thereto, and regulate the air-inlet up to the point of smoking, thus obtaining complete combustion and maximum efficiency. I may add that this regulation is as easy, as efficient and as convenient, as the regulating of the wick in any petroleum lamp. The manner in which we expose a constant surface of oil is by means of horizontal trough-like fire-bars, placed one above another, on which the fuel is maintained at a constant level by means of supply and overflow.

The efficiency of this crucible furnace is really surprising. At a distance of about 1 foot from the fire-bars we melt full crucibles of wrought iron at the rate of about 11 meltings in twelve hours, the last meltings taking only fifty minutes (exceptionally only forty minutes). I will point out that steel-melters generally require four to six hours for each melting, although steel melts at a much lower temperature than wrought iron; and whereas we charge the crucible full (67 pounds) each time, steel melters charge in the same size of crucibles 60 pounds the first time, 50 pounds the second, and only 45 pounds the third time. And whereas crucibles in other furnaces can be used only exceptionally more than three times, we generally (although melting wrought iron) use them six or seven times.

The regularity of this furnace is so great that we can almost work it by the clock instead of by watching the melting.

3. *Treatment of the Molten Metal.*—If I should describe in a few words what we do, when making these wrought-iron castings, it would be this: we take wrought iron, melt it and pour it into castings of any desired shape, without changing its quality of wrought-iron in any way (fibrousness is not a quality, it is a condition), and obtaining castings that are practically solid. For obtaining this result we use what we have described until lately, as "such physic

as we have found most suitable for our purpose." Our physic, however, is not added for the purpose of improving the quality of the metal, as other physic generally, but for altogether another purpose, which I shall explain presently.

I will first draw your attention to the fact, that if we want to make a casting we must have the metal superheated, that is to say, heated a certain number of degrees above its melting-point. If, for instance, we assume the melting-point of wrought iron to be 4000°, and we heat it to that temperature exactly, it is impossible to remove it 6 inches from the furnace before it becomes solidified, and it is thus impossible to make a casting. If we superheat it only a little, we may be able to carry it fluid a few feet to the moulds, but cannot pour any castings. For being able to handle the metal in a practical and convenient way, and pouring it into castings, particularly thin ones, it is thus evidently necessary to have the metal considerably superheated. The way of producing this necessary superheating is to gradually raise the temperature above the melting-point, which operation is generally termed by steel-melters "dead-melting" or "killing." Now this operation of gradually raising the temperature above the melting-point is most injurious to the metal. It is during this operation that the metal takes up gases from the surrounding atmosphere. Practically speaking, no gases are absorbed when the metal is solid. It is after the melting that oxygen, nitrogen, hydrogen, and carbonic oxide are taken up; and for reducing the injury of these gases many admixtures have been used, such as ferromanganese, silicide of manganese, etc., all of which, to a certain extent, remedy the evil, but at the same time change the nature of the metal, and are rather objectionable in one way or another. Now, as a rule, an ounce of prevention is better than a pound of cure; and it is quite evident that, if we could by some means superheat the metal some 300° or 400° without raising the temperature above the melting-point, we should give no opportunity for gases to be taken up. To superheat the metal without raising the temperature above the melting-point; yes, gentlemen, that is what we go in for. There is no play of words in this expression of mine, although I judge from the smiles of several of the members that they consider my words to contain a contradiction. But that is not so; we do exactly what I have said.

It is a well-known fact that alloys melt at a lower temperature than would be expected from the melting point of the ingredients. For instance, tin, bismuth and antimony melt at respectively 440°, 500°

and 700°; but an alloy of equal parts of these three metals melts at about 170°, that is, a temperature lower than boiling water. Platinum, one of the metals most difficult of fusion, melts at a brown heat if a little lead is added. Wrought-iron melts at 4000°; but if carbon (which cannot be melted at all) is added to the extent of 1 per cent., we have tool-steel, which melts at about 1000° less. We have found that the metal aluminum has a very effective influence upon iron in this direction, and also that the addition of aluminum in sufficient quantity for our purpose, has no detrimental influence upon the iron. It is of this property of aluminum that we avail ourselves. We heat the wrought-iron just to melting, but not more; and then, as soon as the metal is molten, we add a small quantity of aluminum, from 0.05 to 0.1 of one per cent., thereby producing a sudden lowering of the melting-point, and obtaining a superheating of, say, 300°, 400° or 500°, sufficient at least for our purpose, to be able to handle the metal in a practical way and pour it into castings. That, gentlemen, is the way in which we produce superheating of the metal, not by gradually increasing the temperature above the melting-point, but by suddenly lowering the melting-point of the metal, thus obtaining it superheated in respect to its new melting-point. You will understand that in this way we give the metal no opportunity to take up gases, which is a very important feature in our invention.

To an insignificant extent, gases are, however, taken up during the melting; but they are released by the suddenly increased fluidity, due to the superheating effect which changes the consistency of the metal from something like syrup to the fluidity of water. The fluidity in fact becomes so great that we can, without difficulty, produce such castings as these samples, which speak best for themselves.

For the benefit of those gentlemen who may feel inclined to immediately begin experimenting to find out some substitute for our aluminum-physic, I will merely mention that out of pure cautiousness lest some one else should find out something equally good and thereby deteriorate the value of our invention, we have deferred taking out a patent for this addition of aluminum, until we had time to go through the most exhaustive and elaborate experiments with every conceivable metal, metalloid and alloy. That is the reason why this aluminum-patent (No. 333,373) was not issued until about 6 weeks ago. And our experience is that nothing else answers the purpose. If added in sufficient quantity, other admixtures always

have some injurious effect. Carbon alone can with advantage be used in an analogous way, and has, in fact, been so used, when hard steel is produced by melting softer steel and thereafter adding carbon in the shape of pig-iron or spiegeleisen.

4. *Mechanical Appliances for handling the Metal.*—If the metal is of ever so good quality, every founder knows what important part the temperature, at which the metal is poured, plays. And if a large quantity of metal has to be poured into a great many moulds, it is not possible with ordinary means to do it or at least not to pour them all at the right temperature. We have several valuable arrangements for accelerating and facilitating the pouring (Patents Nos. 317,063 and 317,064), but I shall refer only to one of them, which I regard as a very important part of the inventions under my control. That is a casting-ladle, provided with a cover and with means for producing a flame of high temperature within the ladle. The production of the flame is quite independent of the tipping of the ladle or the opening of the cover. By making the lining of this ladle so thick that the loss of heat, through radiation, need not be taken into account, heating the ladle to the same temperature as the metal and, after the metal is run in, maintaining a flame of about the same temperature, we can keep the metal in a proper state for pouring any length of time that may be required. By keeping the flame slightly reducing we protect the surface of the metal from oxidation without having it covered with slag, and can, therefore, with the greatest convenience and success pour from the lip, which is, in cases where it is possible, the most desirable way. The flame has its outlet over the pouring-lip, and thereby protects even the jet of metal when pouring.

## Discussion.

In reply to a series of questions, Mr. Östberg gave further interesting information on the subject.

His castings do not require any annealing like malleable castings; they are ready when taken out of the mould. They are thus not subject to risk of warping in an annealing-furnace, or to the risk of getting spoiled altogether, which sometimes happens in an annealing-furnace. There is no uncertainty about the quality, as is always the case both with malleable castings and hand-forgings.

The tensile strength of the castings is generally from 20 to 50 per cent. greater than the raw material, a fact which he ascribes mainly

to the density, although the aluminum seems to have some effect in that direction.

In the petroleum-furnace he can melt hard steel in 30 to 35 minutes, cast-iron in about 20 and brass in less than 15 minutes.

In open-hearth furnaces, he had no hesitation in saying that the aluminum-physic can be used with advantage, if properly arranged and managed, and in connection with the casting-ladle and other appliances.

As for its use in Bessemer practice, he remarked that the influence of the aluminum could here, of course, not have the character of "prevention," but only that of "cure;" and, although his experience, in this direction, had not yet been large enough to justify him in expressing an unqualified opinion, still he had produced ingots of about 0.06 of one per cent. of carbon, which did not rise in the mould at all, were solid and of good quality in every respect.

The price of the aluminum-physic was hardly to be taken into account at all, as regards the manufacture of small castings, or in the production of solid ingots for purposes where the solidity was of importance. The aluminum was added in the shape of an alloy with iron or rather with pig-iron, thus containing some carbon and silicon, which, however, was no objection on account of the very small quantity of physic to be used; it was rather an advantage.

Mr. Östberg's Mitis-foundry, in Stockholm, had been in full operation on a large scale for rather more than a year. His firm formerly had the only malleable-iron foundry in Sweden, but as the Mitis castings have there already replaced the malleable castings altogether, the malleable-iron foundry has been pulled down.

---

## *A CHILLED BLAST-FURNACE HEARTH.*

BY JAMES GAYLEY, BRADDOCK, PA.

THE occurrence of obstructions in furnace-hearths is nothing new to blast-furnace managers. The removal of them is becoming more and more simplified every day. The appliances that can be readily obtained at any works, are so simple in construction and effective in operation that they can overcome the most obstinate condition of affairs that can exist in a furnace-hearth. The old method of opening up tuyeres and notches with sledges and chipping-bars, was

tedious and often futile. The use of the steam-drill, which has been frequently applied, was much preferable, since it possessed the valuable quality of never getting tired; but even with this powerful help, many furnaces have had to be shoveled out. All other methods, however, have been superseded, in point of speed and reliability, by the introduction of the hydro-carbon blow-pipe; and, through the use of this device, the time has arrived when the shoveling-out of stock and the blasting of salamander, on account of an obstruction, can be done away, and the term "chilled up" should become obsolete.

A hearth with iron- and cinder-notch and all the tuyeres full of chilled cinder presents difficulty enough to contend with. But when this is replaced by a material consisting, principally, of chilled iron with only a small admixture of cinder, the case becomes more complicated. Yet it is not one of fruitless endeavor, if treated with judgment, perseverance and a hydro-carbon blowpipe. In many cases, where the hearth is partly chilled or filled with mushy cinder, a good charge of dynamite will give quick relief. But if there is, instead, a solid mass extending above the cooling-blocks, the safest and quickest way is to melt it out by means of the blowpipe—and preferably the one using oil; since, by this plan, the material is heated to the melting point in about one-quarter of the time that would be required with coke and hot-blast. There is, moreover, the further advantage that the oil-blowpipe is able to work effectively in a smaller space.

In the application of this valuable furnace-help to the very obstinate case which is the subject of this paper, the form employed was substantially that described in Mr. Witherbee's paper (*Transactions*, vol. xiii., p. 675), and first used at the Edgar Thomson furnaces, by Captain Jones. The nature of the material forming the obstruction has necessarily much to do with the rapidity of its melting. When there is a large amount of cinder (which is usually the case) and coke or coal imbedded in the mass, the blowpipe will cut very rapidly and keep all hands busy removing the cinder. After this rapid melting has commenced, a very small quantity of oil will be required. But as the material we had to deal with was composed largely of iron, progress was comparatively slow. The small amount of cinder present had a tendency to remain in a pasty condition in the cavity for a long time, interfering with the melting; and in flowing out, it would chill around the mouth of the opening. To obviate this, some salt was thrown in from time to time, which

made the mass very fluid. The use of some of the fusible salts in connection with the blowpipe is of great advantage; and, if fed into the air-pipe and forced out with the blast, they will be more evenly distributed and will prove more effective.

The history of the case to which I wish to call attention is as follows:

On December 31st, 1885, on account of labor-troubles, all the furnaces at the Edgar Thomson works had to be banked very suddenly. It was not until January 20th, 1886, that matters were so arranged as to allow our starting up. Furnace E, which gave us the trouble, had worked more irregularly, before being banked, than any of the others. In August, 1885, the hearth had been obstructed as the result of a slip, and had been opened with the blowpipe. After that, the furnace was frequently troubled with small scaffolds; and the iron, in consequence, was quite variable, the fuel-consumption, for some time after this accident, being as high as 3000 pounds per ton of iron.

When we opened the furnace, on January 21st, everything was found in first-class condition. There was plenty of bright coke at all the tuyeres and at the cinder-notch. At 2 P.M. we turned the blast on, and she started off in good shape. The stoves had been fired with wood, and showed a temperature of 500° F. In one hour after starting, a mushy cinder appeared at the tuyeres. The notch was opened (the cinder-tuyere having been left out) and a good-sized flush of unseparated cinder and iron was obtained. A bar was driven in after stopping up, to insure our getting the hole the next time. An hour and a half later, a second flush was made, of about the same character as the other, but larger in quantity. A bar was again driven in, and everything went along smoothly for two hours more, when, in trying to pull the bar out, we broke it off; after several unsuccessful attempts to drive another one through, the iron cooler, which holds the bronze cinder-tuyere, was taken out to permit our getting a hole higher up. The material here was quite hot, and we were making good progress, when a heavy slip occurred on that side of the furnace, and five minutes after, two more followed in quick succession, on the other side and the back. Cinder ran freely out of all the plug-holes and joints of pipe-connections, closing up five of the tuyeres. At No. 7 tuyere, which is to the right of the notch, a hole, about 3 inches in diameter, was cut in the goose-neck. Through this opening a current of air was projected on the fall in front of the notch—which, with its incessant roar and the clouds of

sand, hurled in every direction, made it almost impossible to accomplish anything. A temporary plug was inserted and drilling was pushed forward as rapidly as possible by relief gangs, without, however, making much progress. The three open tuyeres were blowing through mushy material, and soon closed up. The engines were then stopped. The pressure-gauge, when last observed before stopping, showed 10 pounds, 4 pounds being the normal pressure before the slip occurred.

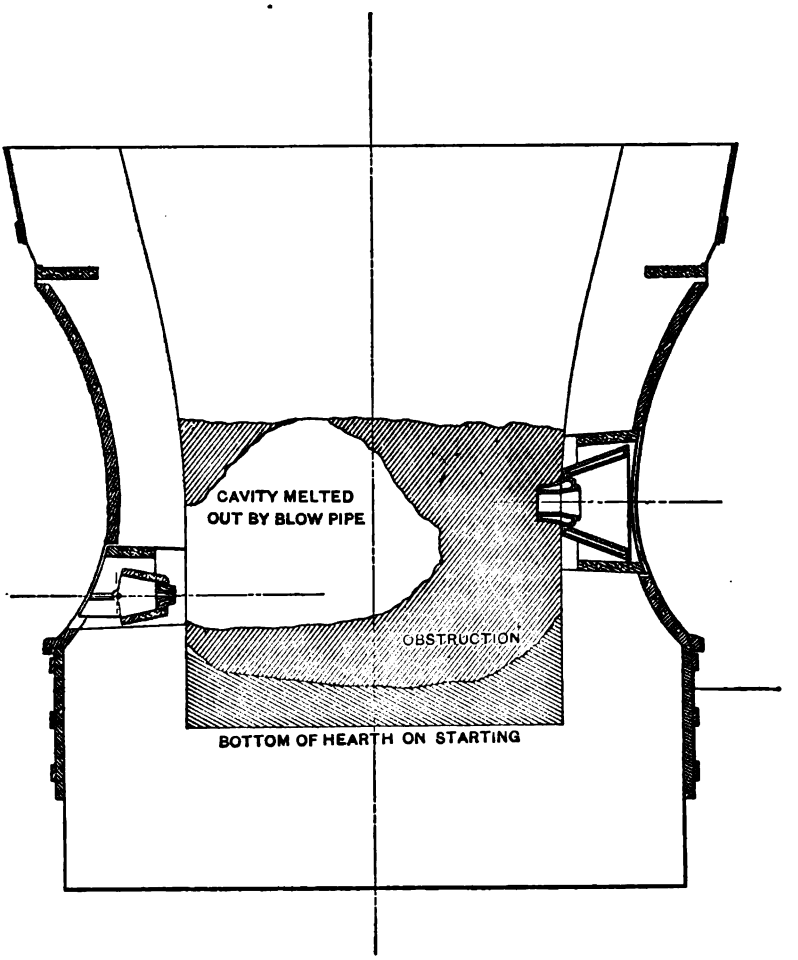
The belly-pipes were taken down with difficulty, as the upper half was filled with iron which had partly solidified. Only two of the tuyeres could be taken out: the others were too firmly imbedded in iron.

A careful examination was made of the condition of each tuyere with respect to obtaining an entrance; but of the whole number—eight tuyeres—only one showed any cinder; and there it consisted simply of a shell about 2 inches thick on the face of the iron.

Arrangements were then made to get the blowpipes at work. Two were fitted up and started by noon on the 22d, one working in the cinder-notch, the other in No. 6 tuyere, to the left. In a short time they commenced to melt; and as the cavity increased in size, the progress was more rapid. For a distance of 18 inches to 2 feet toward the center of the hearth, the material was quite hard and consisted mainly of iron. Beyond that it became softer and showed more cinder. In six hours after we got fairly started, a cavity was melted out, in size about 6 feet long, 5 feet wide, and 4 feet high—or 3 feet above the center of the cinder-notch. The accompanying illustration shows it in section. The crust was then penetrated, and a large quantity of good, hot coke fell through. A tuyere was put in, the cinder-notch closed, and we started off again in a legitimate manner, having no further trouble with either tuyere or cinder-notch from that time on. In opening the tuyeres, the bronze cooler, which holds them, was protected by packing with clay, and by making a channel from the butt of the tuyere outwards with hexagon bricks, having a 6-inch opening. Even in this small space, the blowpipe worked very effectively.

The tapping-hole was opened by the same means; but we were obliged to burn it out several times before we could retain it permanently. In burning out at this place, the usual plan is, to keep on melting until the iron breaks through. This happens, as a rule, when least expected, and frequently just after a cast has been made over the fall, and the hearth has been left comparatively dry. In-

stead of this plan of burning out, it will be found that when the blowpipe has melted in a reasonable distance, and the cavity is well heated up, a tapping-bar can usually be driven through without much trouble. By doing this we were able to save several hours of tedious melting, and could cast with a hearth full of cinder and iron,




Section showing Chilled Hearth of Edgar Thomson Furnace E, January 22d, 1886.
Scale $\frac{3}{16}$ inch = 1 foot.

which is very desirable. In the space of six days after the accident, all the tuyeres were at work; and the furnace gave us no further trouble.

The most interesting feature presented by the obstruction was the presence of such a large quantity of iron. In the material melted

from the cinder-notch, the proportion, as far as we could judge, varied from 60 to 80 per cent. At all the tuyeres, which were opened by the blowpipe, fully 80 per cent. of iron was found; at no time did the proportion of cinder exceed 40 per cent., and it was generally less. The only explanation I can offer for this condition of the hearth is, that the several slips brought down a large amount of reduced ore in a state of fine subdivision, which, absorbing all the heat of the hearth in melting, produced the sudden chilling. Judging from the quantity of cinder that ran out of the plug-holes and pipe-joints after the slip occurred, it seems to have been largely squeezed out in that way.

While managing the furnaces of the E. & G. Brooke Iron Company, at Birdsboro, Pa., I often observed that, when a slip occurred after a period of regular working, the next cast of iron was larger than usual. Particularly was this the case, when the heat in the hearth was sufficient to melt the material brought down. If the temperature is low, or an unusually large quantity of the material is present, it will become thick and mushy, and part of it, sometimes, will remain as a powder. Our practice was to cast as quickly as possible, so as to clear the hearth and bring fresh coke in front of the tuyeres; and we generally got 50 per cent. more tonnage than we would have obtained under ordinary working. Indeed it seemed a mystery, sometimes, where such a large quantity of iron could come from.

The peculiarities of the obstruction above described lead me to think that we have something of the same nature occurring here.

---

## *BIOGRAPHICAL NOTICE OF OSWALD J. HEINRICH.*

BY R. W. RAYMOND, NEW YORK CITY.

THE name of Oswald J. Heinrich first appears among the members of the Institute in the first volume of its *Transactions*, which records that he was elected at the Boston meeting, in February, 1873. That name has stood ever since upon our catalogue of active members. It has appeared frequently in the reports of our debates. It has been attached to many interesting and important professional papers. Henceforward it must hold a place, silent but significant, in the pathetic lengthening list of our departed. From a present

power, it is suddenly transmuted into a sacred memory. To how many of us this change brings a keen personal sense of loss, I need not say. All the older members of our body will certainly both mourn and miss him, whose joyous presence was the very incarnation of that good-fellowship which has inspired our history, while his store of practical experience and wisdom, reinforced by wide and deep scientific study, and placed freely at the service of his brethren, illustrated no less the other and more serious purpose of our existence as a society.

Mr. Heinrich was born in Saxony, April 23d, 1827, and was, therefore, at the time of his death, which occurred at Drifton, Pennsylvania, February 4th, 1886, nearly fifty-nine years old. This period he had so filled with varied activity that, reflecting upon his career, one might well have been led to think him older, while the elasticity and perennial youth of his spirit, and the hale vigor of his body, would have induced the contrary belief.

His father was the secretary of the late King Johann, of Saxony; and the son received the advantage of an excellent education, first at an academy in Dresden, and subsequently at the famous Royal School of Mines at Freiberg, then at the height of its glory. The elder Weisbach was pursuing with enthusiasm that twofold career of instruction and original investigation which redounded so much to his own credit and the credit of the institution; and other great men, each in his sphere, were worthily doing their part to create the modern arts of mining and metallurgy. I mention Weisbach alone in this connection, because young Heinrich was his favorite pupil. Those of us who recall the brilliant and genial professor in his later years can imagine what must have been the joy of companionship with him in his prime. Teacher and pupil had much in common; and it is not surprising that they became intimate.

Heinrich was twenty-one years old when the wave of political revolution swept over Germany. Like all the high-spirited young men of his time, he was caught by it—a not unwilling swimmer. Side by side with his friend and fellow-student Zeuner, afterward an *Oberbergrath* and director of the Freiberg school, he fought on the barricades. The disastrous result of that movement is matter of history. Indirectly, it was a great benefit to this country, though it seemed but a calamity to the Fatherland. It brought to our shores a host of refugees, the most noble and ambitious spirits of Germany, who came as exiles for Liberty's sake, and bestowed upon their adopted country a rich treasure of art, science, and enthusiasm. This

was the best contribution the Old world had ever made to the New, since the landing of the Pilgrims. Among these latter Pilgrims was Heinrich, who came in 1850, and, after getting married, proceeded at once to Tennessee. There he faced, with a stout heart and ready hands, the difficulties of his new situation. He was not ashamed to work; and, as bricklayer, painter, cabinetmaker, etc., he earned his living in Tennessee. Afterward, he moved to Raleigh, North Carolina, and again to Augusta, Georgia, where he practiced as an architect. In 1854, he opened an office in Richmond, Virginia, as architect and mining engineer. To these professions, he added the work of instruction at the Richmond Mechanics' Institute, and in private classes, in drawing, water-color painting, and mathematics.

At the outbreak of the rebellion, a commission in the Confederate army was offered to him. This he refused, not desiring to take up arms against the Union. But he could not get away from the South, where all that he had in the world was involved; and perhaps it is fair to infer that the prospect of a second exile for political reasons was not as attractive to him in mid-life as a similar outlook had been in youth. At all events, he accepted a technical position in the service of the Confederate government, which secured to him the privileges of a non-combatant. He took charge of important mining and manufacturing operations, including the making of gunpowder, and was also employed in the construction of fortifications for the defence of Richmond. In the last year of the war he was superintendent of the Confederate iron mines at Buchanan, Botetourt Co., Va. The collapse of the Southern cause left him at that place, entirely destitute. But he still possessed at Richmond a large and valuable geological collection, the accumulation of many years, illustrating the mineral resources of the Southern States. This was noted as the finest collection of the kind, had received several prizes, and was regarded with peculiar pride and affection by its collector and owner. Leaving his family at Buchanan, and taking a few copper coins, the store of his children's "saving-banks," he made the long journey to Richmond on horseback, arriving at last to find that his great collection had been destroyed in the burning of part of the city, attending its evacuation by the Confederate government, and its occupation by the Federal troops.

Undismayed by this culminating disaster, he reopened his office as architect and engineer in the half-ruined capital, and began life anew. It was about this time that I first met him, making his ac-

quaintance through the late Dr. Justus Adelberg, a man of the same class as Heinrich, and, like him, a refugee of the days of '49. Drawn together by a common love for our Saxon *alma mater*, Freiberg, Mr. Heinrich and I speedily cemented a friendship which was to me a source of pleasure and of instruction for twenty years. In him I found the first of many of our profession who saw the new, the only opportunity for the South in the development of its industry, which would at once repair the waste and assuage the bitter memories of war. With an undying zeal, to the end of his life, he urged this course, and contributed in every possible way to its advancement.

In the autumn of 1865, he went back to Buchanan to bring his family; and here he encountered the hardest blow of all, arriving in time to witness, September 30th, the death of his wife, who had been the beloved companion of so many years of adventure and vicissitude. He was a warm lover of wife and children and home. More than once, during the days of war, he had run the gauntlet between the fires of the two armies, swimming swollen waters, threading mounting passes, and following secret trails, only to snatch a few hours with that dear circle. Now he made a more peaceful but more lonesome journey, descending the James River to Richmond in a canal-boat, and bearing with him the body of his wife. The Richmond *Gesangverein*, of which he was for many years the president, sang over her grave her favorite songs; and the chapter of happiness and hardship in his life was closed. How little seemed the hardship and how great the happiness, those who have heard him talk of those early days can testify. In after-years he married again; and his affectionate disposition was congenially mated, and his home was happy, though the children had grown and gone, and the morning romance was over.

In 1868, Mr. Heinrich became superintendent of the Wythe lead mines at Austinville, Wythe Co., Va., where he remained long enough to repair the effects of bad management and to make important new discoveries of ore. In carrying out this work, he exposed his life with characteristic recklessness, since the necessary careful survey of the dilapidated underground workings obliged him to labor in ground already caving.

In 1869, he took charge of the Midlothian colliery. It was while he occupied this position that he became a member of the Institute; and our *Transactions* show the extraordinary difficulty of his work and the extraordinary ingenuity and courage with which he conducted it. His paper on the Midlothian colliery, in Volume I., pre-

sents a thrilling picture of the hand-to-hand fight with danger and death in which he was for years engaged. I well remember the impression produced by his graphic description of this prolonged encounter—so free from boastfulness, yet so full of the joy of battle and of victory.

In 1875, he resigned his position at Midlothian, and went to Goderich, Canada, to take charge of the operations there in deep boring for salt. Already in Virginia, he had made extensive and careful use of the diamond drill; and his papers on that subject continue to this day the best source of accurate information for the engineer. In the following year, he visited Europe to inspect salt-works and study cognate questions. While there, he received from his old friend, Gerstenhöfer, the agency for certain inventions connected with the ammonia process for the manufacture of soda; and, after his return, he labored hard to secure the introduction of that process in the United States. While he did not personally succeed in starting any enterprise of the kind, it has been done with signal ability by Mr. W. B. Cogswell, another of our members; and the views and arguments of Heinrich have been fully corroborated by the results of the experiment. On this subject also, he has left in our *Transactions* the evidence of his lively interest in technical progress.

In 1878, he accepted the directorship of the Industrial School for Miners and Mechanics, established at Drifton, Pennsylvania, by Mr. Eckley B. Coxe. Mr. Coxe was also a Freiberg graduate, and had been in his day, as Heinrich had been before him, a favorite pupil of Weisbach. He could scarcely have found a better man to carry out his views than Heinrich; and certainly the veteran engineer could not found for his old age a pleasanter harbor—I will not say of rest, for rest was impossible to him; but of peace and freedom. Here he remained to the end; and of his work here he gave, as was his praiseworthy custom, a record to us, in his paper on the Drifton School.

His interest in the development of the South, particularly of Virginia, continued unabated. That State he knew thoroughly—"every cow-path in it," he used to say; the geological map of the State which he constructed was the best in existence; and his comprehensive knowledge of its resources is shown in his paper on the Mesozoic Formation in Virginia, in Volume VI. of our *Transactions*.

It was not given to Mr. Heinrich to achieve wealth, or to link his name with any one great work of engineering. Indeed, the mining engineer's task is not essentially constructive. The problems he

solves, the difficulties he overcomes, the results he produces, are, in their immediate nature, transitory. His highest achievement is the economical destruction of the cruder form of matter that it may be sent forth in a higher form, to be lost in use. His "production" is for "consumption." Yet, if there be a structure of human society, rising like a noble edifice, to which every advance in the comfort, intelligence, and industry of the race contributes a new stone, the mining engineer, whose art is the mother of arts, and the inseparable sister of civilization, is indeed a builder and not merely a destroyer. In this noble work, our departed brother wrought bravely, skilfully, zealously; and it is with an honest pride as well as with a deep and true sorrow that we speak above his bier the last *Glück auf!*

---

## *PECULIAR PHENOMENA IN THE HEATING OF OPEN-HEARTH AND BESSEMER STEEL.*

BY WILLIAM GARRETT, PITTSBURGH, PA.

I HAVE heard it said that the late Mr. Holley made use of this remark: "There is an inherent cussedness about rolls which, so far, no man has been able to find out." I think this can be safely claimed in reference to steel, as there are certain peculiarities about it that are pretty hard to account for.

Previous to the introduction of the Bessemer process there was, as it were, a great chasm between iron and crucible steel; and, outside of what futile attempts had been made in puddling steel, nothing had been done to fill this gap. The Bessemer steel struck a medium between the two, the softest of it not being able to take the place of good iron, while the hardest was not suitable to encroach very far upon the crucible-steel trade. The open-hearth process made quite an inroad into the latter, but only for the lower and cheaper grades; and, beyond a doubt, for the finest grades of tool-steel, the crucible-steel business has a long life before it. On the other side of the line comes the "basic" process, which brings us a step nearer iron; but to fill up the gap completely, comes the Clapp-Griffiths process, which makes a grade of material—call it what you will—that is as soft as iron, welds as readily, and is in a fair way to supersede iron altogether.

For fifteen years, I was in the employment of the Cleveland

Rolling Mill Company, where I had charge of the merchant and rod mills, in which we rolled steel made by the Bessemer and open-hearth processes, which varied in carbon from ten to eighty hundredths. As we were in a great measure pioneers in the introduction of steel to supersede iron, as far as we could go, on one hand, and the cheaper grades of crucible-steel on the other, our experience was both varied and interesting. A large business was done in making buggy- and seat-springs. In spite of getting the analysis of every cast carefully, and of the pains taken in picking out the pig-metal, we often got into trouble with our steel, some being too soft to temper and some too hard or brittle. On analysis, we often found the soft steel, if anything, higher in carbon, and sometimes both hard and soft were precisely the same in carbon, silicon and manganese.

After adopting a mechanical test, which was to roll a test-piece, say, $1\frac{1}{2}''$ wide by $\frac{1}{4}''$ thick, and, by bending it over, judge as to the quality from the way it bent and broke, we got along very well, by using care and judgment. Occasionally we came across some steel, which was chemically according to formula, but which broke very short and brittle. For the required grade of steel, if made by the Bessemer process, we found that from 0.60 to 0.65 carbon was the best suited to our purpose; but when we began to use open-hearth steel, having the formula suited to the Bessemer, we found it would not temper; and we had to raise the carbon up to between 0.70 and 0.75 before we got it to answer the purpose. The reason for this strange peculiarity I could never discover. I may add that the phosphorus, silicon and manganese were practically the same in both kinds of steel.

The softer grades of steel made by the open-hearth process, say 0.10 to 0.13 carbon, were used largely for special grades of wire-rods and for sheets. In the latter manufacture we again came across some very strange results. Some of the steel would roll into sheets as nice and pliable as we could desire, drawing out in length like iron; but some, again, were stiff and rigid; in fact we could do nothing with them. On examining the analysis, we frequently found that the soft and pliable sheets were made from steel a few points higher in carbon than the other; and sometimes both the analyses were the same.

When the manufacture of a low grade (in carbon) by the Bessemer process came into general use (say 0.10 to 0.12 carbon) we again found this strange peculiarity, that although the same in carbon, phosphorus, silicon and manganese, as that made by the open-hearth

process, yet it was very much harder and stiffer. This could be easily noticed in the rolling.

In reference to the "basic" steel I have very little to say, having handled comparatively little of it. I understand, however, that a material can be made by this process that will analyze exactly the same, chemically, as some of the finest Swedish bar used for melting purposes, and yet, when put into the crucible-pot and melted, the result is very different. This surely is somewhat peculiar.

I have had the opportunity in the last six months of handling a large quantity of Clapp-Griffiths steel; and in all my experience, especially in the wire-rod line, I never had any steel that rolled so soft and pliable; and it will stand as high a heat as iron. We have often taken rough, defective, scabby blooms and given them as much heat as an iron pile and, without any delay whatever, put them through the rolls, which welded all defects, and gave us a good finished product. This steel comes nearer to good strong iron than any I have ever seen, and, in my opinion, has a very important part to play in the near future in the iron and steel business. It will do more to supersede puddling than any other product, because it stands a higher heat, welds better, is softer and more pliable than any other kind of steel manufactured at the present time.

Before we adopted our mechanical test to determine the quality and grade of steel, we relied entirely upon the analysis of the chemist; and whenever we sent any steel away, which turned out to be too hard, breaking very short or breaking when testing the springs, we would analyze what was returned. If we found the carbon within certain limits, we claimed that the steel had been burnt or overheated before the rolling. This certainly was at first sight a reasonable conclusion to arrive at. Taking into consideration our past experience in the heating of iron (and it is a well-known fact that overheating or burning iron makes it brittle—the fracture showing the grain coarse—and ruins the quality of the material), nothing was more natural than to come to the same conclusion with steel. Indeed it seemed likely that the effect on our steel would be even greater, seeing that the crucible-steel, on the other hand, had to be heated at a very low heat and with great care. Laboring under this belief, therefore, when steel broke short and brittle, we said it was overheated or burnt. This was a matter of a great deal of annoyance, both to the men we employed to heat the steel, and to the man who had charge of the rolling department, the former claiming that there had been no overheating. In some departments, many heaters were

fined and some discharged. Then the man in charge of the department concerned, would, when complaints of this kind were reported, take special pains and would see almost every piece of a certain lot rolled; but as soon as confidence was, in a measure, restored, another batch of burnt steel would be reported again, and in spite of all the protestations of the man in charge, and the men who worked the steel, that it had not been burnt or overheated, claiming that there must be some other cause for it, the chemist would say, "I have analyzed the steel and find it not different from the general run, which worked well." The opinion of every one was that the chemist was right and that, therefore, the steel was burnt, hence, it broke short and brittle, and to back up their opinion, they would say, "Why, look at the grain or fracture how open it is, and somewhat silvery in appearance."

To save a good deal of needless discussion, I will here say that we are perfectly aware that beyond a certain limit carbon, phosphorus, manganese, and silicon have a tendency to harden steel; and sometimes we traced the trouble to that source. But I now speak of cases in which such results occurred, and could not be accounted for chemically.

But can we tell the quality of steel by the fracture? I claim that the only stage in the manufacture of steel where the quality as to grade of carbon can be determined by the appearance of the grain or fracture is in the crucible-ingot, and that only before it is put into the heating-furnace. Take a spring-steel billet, heat it to the proper heat and, before rolling, cut a piece off. Roll the balance to $1\frac{1}{2}'' \times \frac{1}{4}''$, and after both are cold, break them. The grain in the billet will be very coarse and silvery bright, while the grain in the $1\frac{1}{2}'' \times \frac{1}{4}''$ piece will be close and fine; and yet the quality is precisely the same. The reason is plain. Heating the billet opens the pores or grain of the steel; rolling compresses them again. Now take a piece of this $1\frac{1}{2}'' \times \frac{1}{4}''$ spring-steel, heat it to a bright red, and then let it cool; and on breaking you will find the same coarse grain as in the billet. Now heat it again, retaining one part of the bar in your hand outside the furnace door, until the end inside gets white hot, gradually getting colder as it nears the door. Now plunge it into cold water and break it inch by inch. The first break shows a grain as fine as the finest tool-steel, the next not quite so fine, and so on; the cooler the piece was before putting into the water, the coarser the grain. In that bar will be found many different grades of steel, as far as the appearance of the fracture

shows; yet they are of the same quality as the piece broken off the bar, that had not been dipped in the water, and looked like pot metal.

But, you may say, there is nothing peculiar about this. It is a well-known fact that heating steel opens the grain, rolling compresses it, and dipping hot into water closes it. This is quite true, yet it is most peculiar how many men of good common sense and sound judgment, in spite of this well-known fact, will examine the grain of a bar of rolled steel and say it is good steel, or bad steel, or has been destroyed by being burnt. Do we change the chemical properties of steel by overheating or burning, as it is termed? I find that iron-ore, which contains little, if any, carbon, has to be melted in a blast-furnace under a pressure of hot blast to make pig-iron. The main composition of the former is iron and oxygen and other well-known foreign matters, while the main composition of the latter is iron, carbon, and foreign matters, as in the ore. So, to carbonize iron-ore, we must first melt it by blast-furnace practice, take the oxygen out and put carbon in. Now we may run this pig-iron, as it is termed, in its molten state, into a Bessemer converter, and by forcing oxygen in, force the carbon out; and thus we carbonize and decarbonize, and, before the metal cools, carbonize again, by putting spiegel in the metal after it is blown. This sounds like a satire on the manufacture of steel, though I have only stated facts. One is apt to conclude that to put carbon in or take it out, you must first melt your metal, but the well-known fact that Swedish bar can be carbonized by the cementation process knocks all that theory in the head, so we are still left in doubt.

But do we affect the carbon in the steel bloom by burning or overheating the steel, and, contradictory as it may seem, make the finished product brittle? I claim that we do not; but since assertions do not prove facts, let me give you a case in point, which is another illustration out of many, how old and established theories are sometimes proved wrong by accident. This accident made a convert of me, on the point I have mentioned, for all time to come.

One evening, after I had left the mill, I was sent for in a hurry, as the lever of the damper had broken and the damper had fallen off the stack. In the furnace we had 5-inch blooms to be rolled into $1\frac{1}{2}''$ square for spring-steel (the carbon was 0.74). The heat was just about ready, and the heater had just put on a heavy fire and was putting the damper down when the lever broke. He, in his fright, lost his presence of mind, and did nothing but pull the

doors up. Meanwhile the heat was getting higher and higher, and as it was some little time before I arrived, the blooms had got so hot that the top side of them had melted and run, and some of the metal had taken root, as it were, in the furnace. I told them to take the grate-bars out at once. The furnace and steel began to cool; but my mind was made up that the 4000 pounds of steel we had in the furnace was ruined. However, noticing that some of the blooms next the flue were in pretty fair shape, I began to roll from there, intending to stop as soon as the blooms began to break up in the rolling, as I expected they would do. To be brief, every bloom in that heat rolled well; although some were so much out of shape that we could hardly get them into the rolls. The next day I took a small billet of the bloom that was the most burnt, rolled it into $1\frac{1}{2}'' \times \frac{1}{4}''$, and when we tested it, it turned out "O. K." I had 500 pounds rolled as a sample lot. Report came back: "Sample lot first-class steel, send all like it." I shipped the balance, and had no complaint. I took a piece off the billet to the chemist, but said nothing about the circumstances. The result showed carbon 0.74, the same as the carbon of the cast.

After that I made quite a number of experiments, and all turned out as above. One was as follows: We used a box-pile iron for the sides, top, and bottom, and steel billet crop-ends in the centre (rail-carbon). I took a long crop-end and cut it in two, marked one piece with a cross, piled this in the box-pile, right on top next the iron cover, charged the pile in the hottest part of the furnace, and gave it the hottest roasting we could, so much so, that the pile was like mush; pulled it out carefully and threw it down without rolling. When perfectly cold, with great difficulty we parted the cover, got the marked piece, and sent it to the chemist with the other piece of the same crop-end. The carbon was reported exactly alike in both.

The fact that steel will not be rendered brittle or lose any of its properties by overheating, may not be new to many, but it is not by any means commonly known and admitted. I would not be surprised if I should be severely handled for my heresy, so common is the belief that it is injurious to heat steel as high as iron. So I want to repeat that I confine my remarks and assertions to Bessemer, open-hearth, and Clapp-Griffiths steel, and that only after it has been bloomed. In what I have said I have only spoken of what I know, and testified to that I have seen. This incident happened over six years ago, and since that time I have experienced many

things that have seriously impressed on my mind that our method of heating steel at such a low heat was wrong. Strange as it may appear, I am positive that if you take an iron pile and a steel bloom and overheat both, you will find when rolled, that the iron is ruined in quality, while the steel is as good, if not better in quality, than it was before it was heated. Why should we be afraid to heat our steel? Is it not common practice for all crucible-steel makers to heat their highest grades of tool-steel to a welding heat to weld up the seams? Is not a Bessemer, open-hearth, or Clapp-Griffiths ingot more porous and honey-combed than crucible-steel? Hence the greater reason for heating to a welding heat. Is there a steel manufacturer who has had complaints that his steel was seamy? This would not have been the result had you heated your steel to a welding-heat, and then, by hammering or rolling with a light reduction, welded up the streaks in your bloom, which are the round pores of your ingot elongated. The only reason I can think of, that all steel should not be treated in this way, is not that it would injure it in any way, but that it would add to the cost, since the waste in heating would be greater, and would curtail product with the same plant.

I will venture to predict that the future requirements of the steel trade will demand this method of heating steel, or a very much improved method of making sound ingots. In either case, I am of the firm opinion that overheating steel, as it is termed, is not injurious to the quality if it is allowed to cool again, so that it will stand rolling.

---

## *NOTES ON THE CONSTITUTION OF CAST-IRON.*

BY C. B. DUDLEY AND F. N. PEASE, ALTOONA, PA.

THOSE who have worked a good deal on the chemistry of pig-irons of which the physical properties were known, cannot fail to have been struck by the remarkable want of relation between the physical properties of different samples, and the ultimate chemical composition. It is very well known among foundrymen that irons which will give say ½ inch of chill, and are, therefore, approximately the same in chemical composition, are very far apart, many times, in their physical properties. The foundryman's tests for strength are, of

course, crude, and the composition as determined by the chilling power is not definite; but when two different irons which will give nearly the same chill under the same circumstances differ in physical properties so widely, as is revealed by the ordinary method of testing pigs in the yard, even the most stupid observer cannot fail to recognize the difference. We ourselves have seen pigs of approximately the same size and giving approximately the same chill, from different piles of iron, one of which would break when dropped from the height of the shoulders across an ordinary breaking-block, while the other would require to be thrown with full force across the same breaking-block three or four times before suffering fracture. To such an extent has this difference between the physical properties and the ultimate chemical analysis of pig irons been observed, that many intelligent foundrymen do not hesitate to say that the chemistry of pig iron is valueless, at least for indicating anything in regard to the strength.

In our work on pig-irons in connection with the regular work of the Penna. R. R. Laboratory, we have run across the above peculiarity many times, not only in the pig-metal but also in the foundry-product; and not a little study has been devoted to trying to solve the problem which has thus presented itself. With a firm belief that when the chemistry of pig iron is completely understood, it will prove a valuable assistance to the foundryman in his work, we have made many experiments, trying to get a clue and an explanation of the puzzle. With a hope that the work already done may serve as an entering wedge, and stimulate others to take up this interesting problem, we present herewith the results of some of our experiments.

As showing how completely the ordinary ultimate chemical analysis of cast metal fails to explain or even agree with the ordinary conceptions in regard to the relation between the chemistry and the physical properties, we subjoin the analyses of two cast-iron car-wheels. Both wheels were of approximately the same weight, both were cast in the same kind of mould, and, so far as could be judged by the condition of the wheels, both were poured at approximately the same temperature. One of the wheels had been in service, the other had not. One of the wheels, which we will call the good one, which had not been in service, required 150 blows with a 25-pound sledge to break a piece out. The other had been in service, and required 8 blows with the same sledge to break a piece out. We are well aware that the method of testing the strength of cast metals by

sledging is not definite; but it is a practice very common at foundries, and while it is impossible to draw fine distinctions, wide differences are as readily indicated in this way as in any other. One point further. Hundreds of tests at the Altoona Wheel Foundry indicate that the service of a wheel makes no practical difference in the number of blows required to break a piece out, and we think it fair, therefore, to suppose that the poor wheel did not suffer in this respect from its service. A cracked wheel betrays itself with the first blow by the sound; and the poor wheel in this case was not cracked. The following are the analyses:

| | Good Wheel. | Poor Wheel. |
|---|---|---|
| Total carbon, | 3.84 per cent. | 3.53 per cent. |
| Graphite, | 3.30 " | 2 36 " |
| Combined carbon, | 0.54 " | 1.17 " |
| Silicon, | 0.69 " | 0.65 " |
| Phosphorus, | 0.43 " | 0.52 " |
| Manganese, | 0.13 " | 0.12 " |
| Sulphur, | 0.12 " | 0.19 " |

As will be observed from the above analyses, the total carbon is 0.31 per cent. different, the larger amount being in the good wheel. The total silicon is only 0.04 per cent. different, the larger amount being in the good wheel. The phosphorus is 0.09 per cent. different, the larger amount being in the poor wheel. The manganese differs only 0.01 per cent., the larger amount being in the good wheel. The sulphur is .07 per cent. different, the larger amount being in the poor wheel.

The most remarkable difference is in the graphite and combined carbon, which of course vary inversely with each other: that is, in the same wheel the higher combined carbon, the lower graphite, and *vice versa;* but to our astonishment, perhaps, the highest combined carbon is in the poor wheel, whereas, with the ordinary conception of combined carbon, we would expect greater strength to accompany the higher combined carbon. Perhaps, however, the most remarkable peculiarity of the whole subject is that with two pieces of cast-metal treated approximately alike, poured at approximately the same temperature, and cooled at approximately the same rate, with very slight differences in the total amounts of the other constituents, the combined carbon should be so extremely wide apart. No one can fail to be struck, we think, with this remarkable difference—0.54 per cent. in the good wheel and 1.17 per cent. in the poor wheel, of combined carbon—and no one can fail to ask himself, how it happens under the circumstances, that the amounts

of combined carbon in these two wheels are so different. Evidently some causes as yet unexplained determine the larger amount of combined carbon in the poor wheel; and also, so far as the indications of the ultimate analysis, the very great difference in strength of these two wheels is in some way connected with this difference in combined carbon. In other words, there is not sufficient difference in any of the other constituents to account for it. We are confident no one accustomed to working on pig-iron would say that 0.09 per cent. difference in phosphorus in a total of 0.52 per cent. would make so great a difference in strength.

We have made a very large number of experiments with these two wheels, and upon other metal, including pig-irons; and we must frankly confess that we have not yet succeeded in finding anything that is completely satisfactory to us, as an explanation of this puzzle, nor does our reading or study of the literature on the subject, throw much light upon it. What follows, therefore, must be regarded more as a record of experimentation than as mature conclusions. The field opened is apparently broad, and there is very much need of work in this direction; and the principal object of this paper is to stimulate inquiry and get other workers into the field.

We find by treating fine borings with a dilute solution of hydrochloric acid, about 2.50 per cent. HCl, that a part of the metal goes into solution, and a part remains behind. In the two wheels above referred to, a larger percentage of residue is left in the poor wheel than in the good one. We have not followed out each of the elements completely yet; but as far as we have gone, we find as follows: A large portion of the metallic iron goes into solution, all the manganese goes into solution, and a portion of the phosphorus disappears, and a portion of it stays with the residues. The sulphur we have not followed out completely; but a portion of it, at least, disappears. The silicon apparently all goes into solution, except perchance such as may be in the metal as slag. In working on other samples, we have found the silicon in the residue, however, excessively small, and conclude, therefore, that the amount of slag in pig-metal is slight. As near as we can determine, with the work we have already done, the residues consist in part of phosphide of iron, graphite, and separated carbon set free by the dilute acid. These in amount do not differ widely in the two wheels. A direct determination of the phosphorus in the residues from the good and poor wheels, showed in the good wheel 0.30 per cent. and in the poor

wheel 0.32 per cent. Also, there are strong indications that all the carbon, or practically all the carbon, remains in the residue.

In addition to the phosphide of iron and the carbon, we find in the residue what is apparently a compound of iron and carbon, and may, perhaps, best be called carbide of iron. The amount of this carbide of iron is different in the two wheels, being by far greater in the poor wheel. This carbide is gray in color, and apparently granular in structure. It seems to exist in the cast metal as little granules, breaking up the continuity of the metal. We have not yet succeeded in determining the composition of this carbide of iron, nor have we yet succeeded in finding methods that would enable us to distinguish between the amount of carbon in this carbide, and the graphite, and the carbon, if any, set free by the dilute acid. There seem to be indications of two things: first, that the carbon in pig-irons exists in three forms, namely, as graphite, as carbide of iron, and possibly as combined with the iron in the same way that it is combined with the iron in steel, a form which we may venture to call strength-carbon. Second, there are indications that the carbide of iron before referred to is the principal cause of the great difference in strength between the good and poor wheel.

If, on more mature study, these two statements should prove to be correct, it would seem that the constitution of pig-iron, and, in fact, of cast-iron in general, would not be very difficult to explain. The iron might be regarded as made up of strength-producers and weakeners, the strength-producers forming the frame-work or the mass of metal, and the weakeners being interspersed through the mass in a more or less granular or crystalline form, and interfering with its continuity. The metallic iron, the metallic manganese, the silicon perhaps, and the strength-carbon may be regarded as the strength-producers, while the graphite, the phosphide of iron, the sulphide of iron, and the carbide of iron, together with the slag, and oxides, if any are present, might be regarded as the weakeners. It is not difficult to conceive, we think, that any granular body, be it a grain of sand, a grain of graphite, a grain of crystallized phosphide of iron or sulphide of iron, or a granule of carbide of iron, occurring in the mass of either a piece of steel, a piece of wrought-iron, or an alloy composed of metallic iron, manganese, silicon and carbon, would by its presence interfere with the continuity of the metal, and diminish its strength. If, in addition to the graphite, the phosphide of iron and the sulphide of iron, which have for a long time been known to be present in pig-irons to a limited extent, it

should be found that a granular carbide of iron is also a constituent, we cannot help thinking this same carbide will throw much light on the very wide difference in different samples of cast-iron. We have treated a large number of samples both of pig and cast metal with a dilute acid as before described, and we find this gray granular carbide so far as can be determined by the eye, always present and always larger in amount the poorer the metal. As previously stated, however, the methods for determining the amount of this carbide and the amount of graphite and strength-carbon have yet to be worked out. Of the existence of the carbide there seems little doubt. Duplicate tests on the same sample, with exposure to the acid for different periods of time from four to twenty-four hours, give approximately the same total residue unacted on. In other words, there is strong evidence of the existence of a compound of iron and carbon, which is insoluble in 2.5 per cent. hydrochloric acid.

There are very many interesting questions which might be asked, and undoubtedly will occur to all. Answers to these questions will have to be obtained by further study. The most important one perhaps is, why does this carbide form in certain irons and not in others? There are indications that it is characteristic of repeated meltings in the cupola, and there are also indications that the presence of basic slag prevents its formation.

It is earnestly hoped that earnest study will be put on this interesting problem. The commercial results connected with it are something enormous. Some furnaces uniformly make strong irons, others uniformly weak irons. Is it not possible that a change in practice which would diminish the amount of carbide of iron, would change the weak iron to a strong one? Also, as is well known, scrap can only be used to a limited extent in foundries. If we knew how to prevent the formation of this granular carbide of iron, is it not possible that scrap could be used to a very much greater extent than at present? We are confident that the man or men who first explore this field and give us a complete understanding of the constitution of pig-iron, as well as a method of controlling its composition, will certainly cause iron metallurgy to take an enormous stride forward.

[NOTE BY THE SECRETARY.—For further observations in connection with this subject, see the remarks of Dr. Dudley and Mr. Ford, in the discussion following the paper of J. P. Witherow on "The Clapp-Griffiths Converter—Later Practice and Commercial Results," printed on a subsequent page of this volume.]

## *GEOLOGY OF THE LOW MOOR, VIRGINIA, IRON-ORES.*

BY BENJ. SMITH LYMAN, NORTHAMPTON, MASS.

THE Institute, in June, 1881, visited Low Moor in Alleghany County, Virginia, on the Chesapeake and Ohio Railway, seven miles easterly from Covington. Having occasion myself, a few days later, to make a very hasty geological reconnaissance of the iron-ores there, and finding them to be somewhat different in age from what was said to be the opinion of some of those who were there with the Institute, I have thought it worth while to bring the matter up again at the present meeting.

According to the opinion quoted, the principal ore-banks belong to the Oriskany sandstone; and that seems to be the view entertained of the same ore in that region by Prof. Wm. B. Rogers in his reports of 1837 and 1838. It is likewise given by Prof. J. L. Campbell in a paper on the Rich-patch iron region in *The Virginias* for December, 1880 (vol. i., p. 189). A comparison, however, of the section at Low Moor with sections in Pennsylvania, shows clearly that the main ore-bed is the same as that of the bottom part of the Marcellus shales (part of Pa. and Va., No. VIII), a short distance above the top of the Oriskany sandstone (No. VII). The Upper Helderberg limestone is absent at Low Moor, as indeed it is at many places in Pennsylvania, and that is perhaps the reason why the ore has been thought to belong to the Oriskany sandstone.

The ores and their accompanying rock-beds, are exposed in three or four folds near the Low Moor iron-mines on Fork Run and, as described and pointed out by Mr. Geo. T. Wickes, who had in his management of several years' duration become well acquainted with them, are as follows, from above downwards:

| | FEET. |
|---|---|
| Black slates, very thick, . . . . . | ? |
| Light gray shaly clay (Ore-bank No. 1) at least, . . . | 34 |
| Blackish-gray shaly clay (at No. 9), . . . . . | 6± |
| Brown sandstone, 2 feet (at No. 3) to 8 feet (at No. 9), . . | 5± |
| Brown hematite ore, 9 feet (No. 9) to 25 feet (No. 7) to 35 or 40 feet (No. 3) to 70 feet (No. 4) to 10 or 12 feet (No. 4), say, | 15± |
| Sandrock or flint, . . . . . | 5± |
| Clay, over, . . . . . | 20? |
| Sandrock ("40? or 50? feet"), . . . . . | 45? |
| Limestone, 30 to . . . . . | 35± |
| Dark gray, inclined towards dark blue, shale, . . . . | 100? |
| Limestone, . . . . . | 35± |

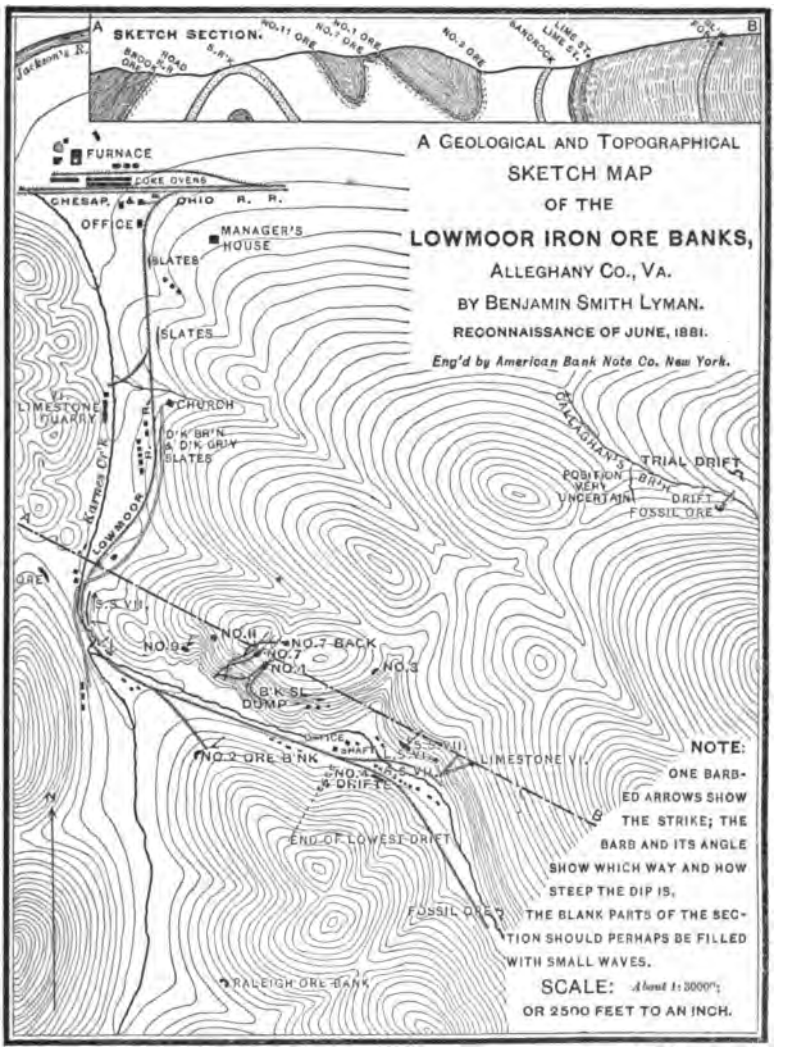
| | FEET. |
|---|---|
| Shale, 300? feet or more, | 300? |
| Heavy whitish flinty sandrock, 40 to 50, | 45± |
| Fossil ore, 16 inches to 2 or 3 feet, | 1½ |
| White clay, 10 to 12 feet, | 11± |
| Yellowish-streaked, less white sandrock, 40 to 50 feet, | 45± |
| Black ore, 4 to 5 feet, | 4½± |
| Gray shales, | 100?? |
| Red shales, | ? |

The accompanying illustrations will further explain the descriptions and discussions which follow. Fig. 1. is a geological and topographical sketch-map of the locality; Fig. 2, a comparison of several geological sections, as shown by the title placed over each.

By comparing the upper part of the drawing of this section with the drawing of the section for Perry County, Pennsylvania, given in H. D. Roger's *Final Report on the Geology of Pennsylvania*, 1858 (vol. i., p. 355), and again in Lesley's *Iron Manufacturer's Guide*, 1859 (p. 652), and comparing the lower part with the drawing of Prof. Campbell's section of Wilson's Hill, Clifton Forge (only half a dozen miles easterly from the Low Moor Mines), in his paper above cited, it will be seen very plainly that the top of the column including the brown hematite belongs to the Pennsylvania and Virginia formation No. VIII (or the Marcellus shales of New York); that the sandrock next below is No. VII (the Oriskany sandstone); that the two limestone-beds with shales between are No. VI (the lower Helderberg limestone); that the shales next below and the Fossil ore and the Block ore belong to No. V (the Clinton group); and that the gray shales and red shales at the bottom belong to No. IV (the Medina sandstone). The section of No. VIII in Pennsylvania, as described by Dr. Henderson, is also given for comparison (see the *Guide*, etc., p. 650); and in the thickness of its beds corresponds closely to that of Perry County. It is mentioned by Prof. Rogers (*Final Report*, vol. i., p. 355, quoted in the *Guide*, p. 652) that "the whole group thins southeastward," and that "the Clay limestone does not exist at the Susquehanna in the base of the Kittatinny Mountain." Prof. Campbell speaks of identifying the beds of No. IV in his section by their lithological and fossil features, and the beds below it as No. III (Hudson River shales) by characteristic fossils. It will be seen, however, by a comparison of his section with the drawing of one of the Clinton group in Pennsylvania, given by Prof. H. D. Rogers and quoted by Dana in his *Manual of Geology*, p. 234 (1864), that the correspondence is so remarkably

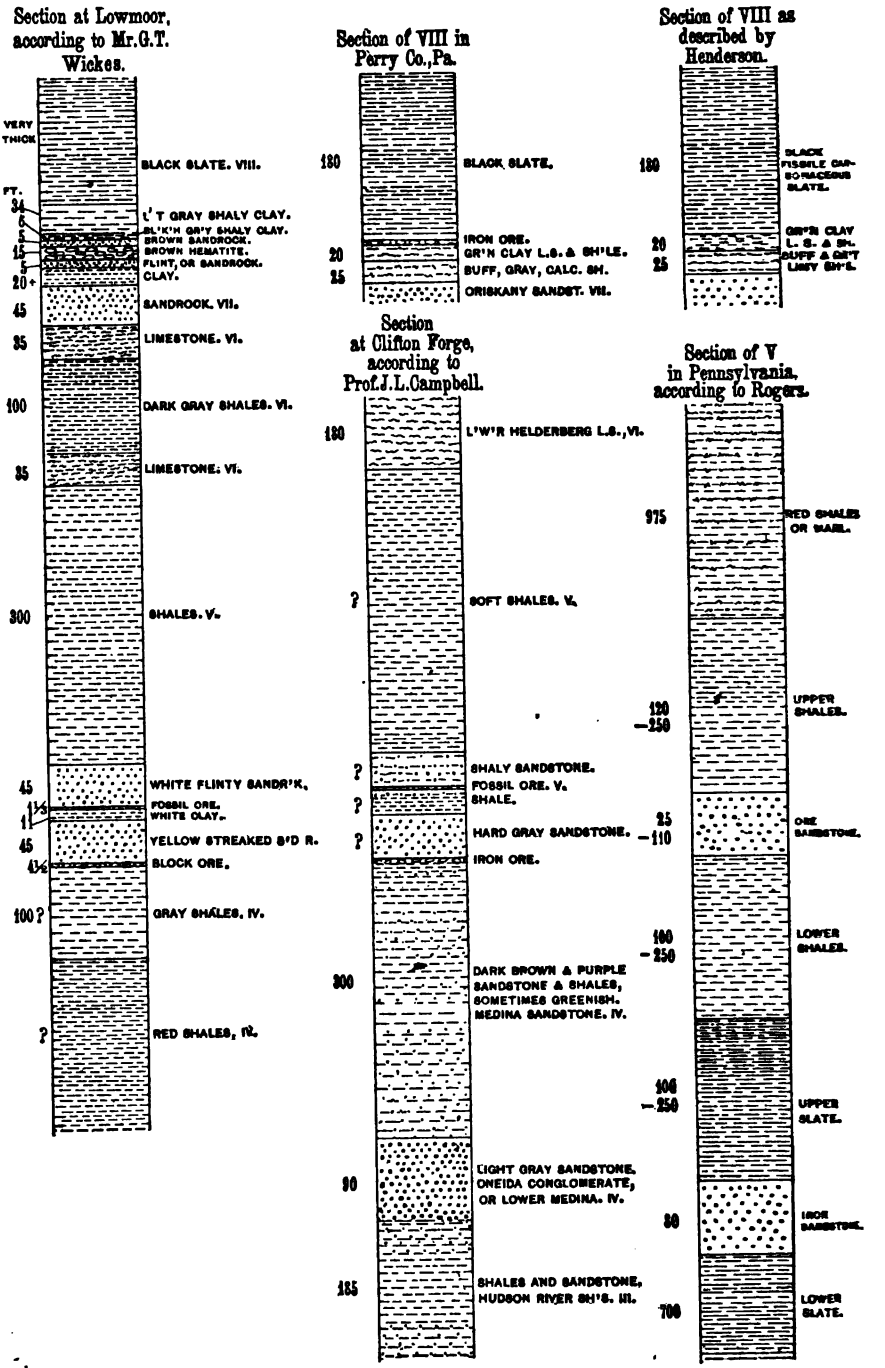
close as to make the identity of the rocks of both appear highly probable (though possibly a mere coincidence), and that even the sand-rock and shales at the bottom were reckoned by Rogers (per-

FIG. 1.




haps owing to a lack of fossils) as belonging to No. V. In either case the fossil and block ores belong to No. V; and our section at Low Moor compared with the Pennsylvania sections makes it clear that the brown hematite of the principal workings belongs to No. VIII.

FIG 2.


Section at Lowmoor, according to Mr. G.T. Wickes.
VERY THICK
BLACK SLATE. VIII.
FT.
34
6
5
15
5
20+
L'T GRAY SHALY CLAY.
BL'K'H GR'Y SHALY CLAY.
BROWN SANDROCK.
BROWN HEMATITE.
FLINT, OR SANDROCK.
CLAY.
45
SANDROCK. VII.
35
LIMESTONE. VI.
100
DARK GRAY SHALES. VI.
35
LIMESTONE. VI.
300
SHALES. V.
45
WHITE FLINTY SANDR'K.
1½
FOSSIL ORE.
1
WHITE CLAY.
45
YELLOW STREAKED S'D R.
4½
BLOCK ORE.
100?
GRAY SHALES. IV.
?
RED SHALES, III.
Section of VIII in Perry Co., Pa.
180
BLACK SLATE.
20
IRON ORE.
GR'N CLAY L.S. & SH'LE.
25
BUFF, GRAY, CALC. SH.
ORISKANY SANDST. VII.
Section at Clifton Forge, according to Prof. J.L. Campbell.
180
L'W'R HELDERBERG L.S., VI.
?
SOFT SHALES. V.
?
SHALY SANDSTONE.
?
FOSSIL ORE. V.
SHALE.
?
HARD GRAY SANDSTONE.
IRON ORE.
300
DARK BROWN & PURPLE SANDSTONE & SHALES, SOMETIMES GREENISH. MEDINA SANDSTONE. IV.
90
LIGHT GRAY SANDSTONE. ONEIDA CONGLOMERATE, OR LOWER MEDINA. IV.
125
SHALES AND SANDSTONE. HUDSON RIVER SH'S. III.
Section of VIII as described by Henderson.
180
BLACK FISSILE CARBONACEOUS SLATE.
20
GR'N CLAY L. S. & SH.
25
BUFF & GR'T LIMY SH'S.
Section of V in Pennsylvania, according to Rogers.
975
RED SHALES OR MARL.
120 — 250
UPPER SHALES.
25 — 110
ORE SANDSTONE.
100 — 250
LOWER SHALES.
100 — 250
UPPER SLATE.
80
IRON SANDSTONE.
700
LOWER SLATE.

The identification of the main ore-bed with that of the Marcellus shales has some practical importance, since it may in consequence be reasonably expected now, that the character of the bed in its origin, persistence and thickness, will correspond more with the Marcellus ore-bed, so valuable in the Juniata Valley and southwesterly towards the Potomac, than with the uncertain, poor deposits of brown hematite found at places in the same region along the outcrop of the Oriskany, evidently the product of leaching from beds of ferruginous rock.

The Marcellus ore-bed, on the contrary, is originally a bed of blue or gray carbonate of iron interbedded with the other rocks, and at the outcrop and down to water-level or the limit of atmospheric influences, becoming weathered to brown hematite. The bed and its ore-banks are described not only in Rogers' *Final Report* and in Lesley's *Guide*, but later in the reports of the present geological survey of Pennsylvania, especially in those for Perry, Juniata, Mifflin, Huntingdon, Blair, Fulton and Bedford Counties (F, F2, T, T2, T3). It is needless here to quote every separate place; for the substance of the whole is briefly summed up by Prof. Lesley in his *Guide*, as follows (p. 650): "The iron-ore lies over the limestone near the bottom of the black coal-slates, and is a gray or lead-colored proto-carbonate, weathering along the outcrop (and sometimes in the body of the bed) into the common porous earthy brown hematite. It is in all respects a fac-simile of the carbonates of the coal-measures; and is in fact a prophecy of them,—as the black slate in which it lies is of the black slates of the coal-measures." Also in his preface to vol. F (1878, pp. xvii. and xviii.) he speaks as follows: "A layer of brown hematite overlies the limestone next to be described. It is constant, but variable in thickness, sometimes a mere trace; often ten or twelve feet thick. Bunches of it occur even thicker. It is sometimes of even size for long distances and then suddenly thins out. Large and profitable ore-banks have been worked in it. In closely folded synclinals of Oriskany sandstone, containing no black shales, no ore need be looked for. Where the ore-bed is good at the surface, there occurs a change of good ore into poor ore at a depth of from 20 to 50 yards; on high ground, cut by deep cross-ravines, the good ore continues to a still greater depth. Below the limit of change, the bed consists of an impure earthy carbonate, or dirty clay-iron-stone; which, deeper still, turns into a dark pyritous clay."

It is perhaps not too bold to take some exception to the last clause, if it be intended to mean that the carbonate is a continuation or a

product of the pyritous clay. It may very well be that the bed of carbonate may in some places be found to be irregular or lenticular in shape, to grow thinner, or to disappear in digging deeper, and that in its proper place there may be nothing left but the pyritous shales, within which, to be sure, the bed at any rate occurs; but it can hardly be that pyrites would be changed within the bedded rocks below water-level into carbonate, a change that could take place only with the help of the oxidizing influences of the atmosphere.

It is obvious, moreover, that along the outcrop of the pyritous Marcellus shales there may here and there be deposits of brown hematite, formed by the atmospheric oxidation of the pyrites into sulphate of iron, its leaching out and accumulation on the surface of the ground in the ordinary way through decomposition (say by calcareous waters), and further oxidation and hydration to brown hematite. Some such superficial deposits from leaching might well, from their position, be mistaken for the outcrop of the great Marcellus ore-bed; and that has, perhaps, been the case in particular with the Elizabeth and Baker ore-banks near Altoona (Lesley's *Guide*, p. 586), where there is no conformity of the ore with the other rock-beds, but an obscure horizontal bedding at right angles with them.

At Low Moor, however, the ore-bed appears to be quite conformable to the other rocks, and, so far as explored, seems to be perfectly persistent, and of very good though variable thickness, in some parts, indeed, quite extraordinarily thick, possibly by a doubling together of narrow folds. It has nowhere been dug deep enough in level to show the ore in the form of carbonate. One shaft had in 1881 been sunk 65 feet deep below the level of the brook without any change in the character of the ore from the usual brown hematite; but evidently the shaft had not yet reached the limit of depth to which surface waters once, either recently or at some former time, percolated through the ore, finding doubtless a way to escape through the pores of the bed, and, perhaps, of the superficial alluvial earth to the level of Jackson River itself—possibly at a time when the channel of that river was even lower than it is now.

The position and thickness of the ore-bed, and the extent to which it had been explored in 1881* may be perceived from a

* No detailed later information is at hand; but I am assured that later developments have not materially affected the geological problem as here discussed.

description of the separate banks. Southwesterly from the shaft, on the hillside close at hand, there is the No. 4 ore-bank, where a certain amount of ore has been taken from the outcrop by open-cutting after stripping off the surface-wash, and four drifts at different levels have been driven into the hill. Standing in front we see these drifts, one nearly above another, to indicate, the two lowest a dip about vertical, and the three upper ones a dip somewhat reversed, and consequently steep towards the southeast, growing steeper (less reversed) upwards; and in the shaft below the lowest drift the dip is said to be steep towards the northwest. The lowermost of the four drifts runs horizontally into the hill "1100 or 1200 feet," without change of character in the ore, which is said to average some 20 or 25 feet in thickness, though at one point it is only about 10 feet thick. In one of the four drifts the bed is said by Mr. Wickes to have been found to be 60, or even 70 feet thick. The stripping has now been abandoned and the drifts alone are worked here, and they only in preparation for the time still in the future, when the ore must be taken chiefly from underground. One of them is driven so far already as to be within 30 or 40 feet of meeting the drift of Raleigh Valley. The Raleigh Valley drift has now been abandoned for some years, but the ore is said to be of the same good quality and thickness as on the No. 4 side of the hill. The shaft (10 feet by 16 feet, vertical and very handsomely timbered) is said to have been dug for the upper 25 feet in loose alluvial material and the rest of the way in solid ore, but so porous that there is very little water, as there would seem to be some lower outlet by which the bed is naturally drained. At the time of my visit the bottom of the shaft seemed to be reaching the lower (southeast) side of the nearly vertical ore-bed. On the northeast side of the valley, still in line with the Raleigh bank, No. 4 bank and the shaft, there is the No. 3 bank, where the open-cut working has been abandoned and a drift driven, in which at 100 feet from the surface the ore is said to be 35 or 40 feet thick. This line of ore-banks is on the first outcrop of the ore-bed as you go northwesterly from the Rich-patch Valley.

From them the ore-bed, dipping northwesterly, forms a basin, and rises again to the surface at No. 2 bank (on the same side of the valley with No. 4 and some 500 yards down stream), and at No. 1 bank (on the opposite side of the valley, the same side with No. 3). At No. 2 there are two drifts besides surface stripping, and the place is still actively worked in the open-cut. At No. 1 there is a

large open cut, where the stripping has become so heavy that the working is abandoned. The ore dips southeasterly, and is covered by gray clay that "must be 40 feet thick." "No. 7 Front" is only a few yards distant to the northwest of No. 1; and the ore has been found to form a small saddle between the two, and consequently at No. 7 dips likewise southeasterly (some 40 degrees), but is seen in the bank itself to form another saddle, and to dip about vertically on the northwesterly side. The bank is an open cut, now abandoned on account of the heavy stripping; but just across the hill, a few yards to the northeast, work is still carried on with stripping at "No. 7 Back." The ore is there about 25 feet thick. From these No. 7 banks the ore plunges northwestward, forming a basin, and rises again with a southeasterly dip of some 55° at No. 9 and No. 11 ore-banks, on the same side of the Karnes Creek Valley. The open-cut work at No. 9 has been abandoned, and a drift has been driven in preparation for underground mining on a large scale. The ore-bed is called 9 feet thick here. No. 11 is an open-cut (now abandoned). The rock beds rise at these banks so as to form a saddle to the northwest; but some 700 yards further down stream ore has been found, it is said, in a small digging on the opposite (west) side of Karnes Creek; and again on the east side, northeasterly from that digging, it has been met with at the bottom of two wells, from which the water soaked away through the ore and disappeared, when they were deepened so as to reach it. No further outcrop of the ore to the northwest is known. But on the hills to the west of Callaghan Branch there is an outcrop of brown hematite, apparently of the same bed, with one imperfect natural exposure of ore that seems to be in place and at least some 6 feet thick.

The ore is found partly solid, which is taken in the form of lumps to the furnace; and partly soft, loose, and earthy, which is washed to remove the sandy impurities.

The fossil-ore of the Clinton Group (V) was at first the only ore known at Low Moor, and was mined on Fork Run for a time; but was abandoned after the discovery of the much thicker deposits of the brown hematite of the Marcellus bed (VIII). The thickness of the fossil-ore is said to have been about 16 inches, and by my own measurement was about 16½ inches at an old bank just re-opening on Callaghan Creek. That is about the same as the ordinary thickness of the fossil ore-bed in Pennsylvania, 16 or 18 inches. There is no evidence at hand as to how far the Low Moor fossil-ore is of

workable quality, and how much depends upon its having weathered near the outcrop and above water level.

The block-ore appears never to have been worked, and not to be fully exposed now in place; but Mr. Wickes said it was "four or five feet thick." Pieces of it lying on the ground looked very siliceous, and, perhaps, hardly rich enough in iron to be profitably workable.

---

## *IRON-ORE DEPOSITS OF SOUTHERN UTAH.*

BY W. P. BLAKE, NEW HAVEN, CONN.

ONE of the most remarkable iron-ore districts of the world is found in Southern Utah, in Iron County, about 270 miles south of Salt Lake City, and 10 miles west of Cedar City.

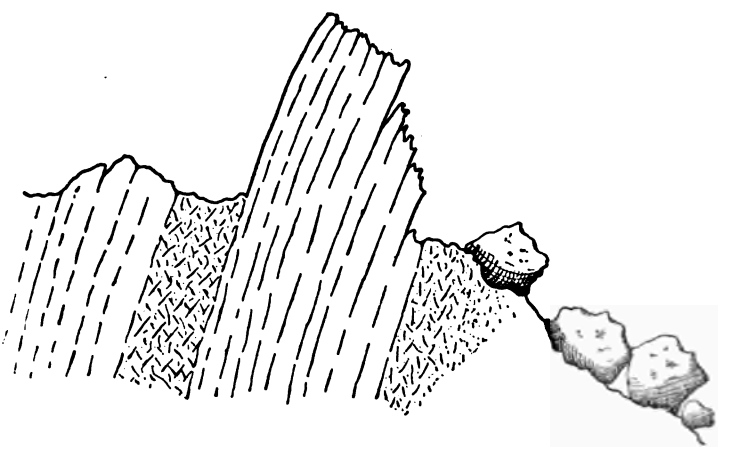
This region has long been known in a general way; but, being at present somewhat difficult of access, it has been rarely visited by any of our members. Professor Newberry has published somewhere a short description. Last year, by the invitation of J. R. Walker, Esq., of Salt Lake City, one of our associate members, I formed one of a party, including Professor G. W. Maynard and W. S. Keyes, to visit and inspect the region. A special car was placed at our disposal by the courtesy of Hon. John Sharp, Superintendent of the Utah Central Railway. From the present southern terminus of the road at Milford, a drive of 55 miles took us to Cedar City, about 10 miles east of the iron region.

The ores outcrop in a low range of hills or mountains, and stand out in such bold relief from the general surface, and are so massive and jet black, that they may be seen for miles before they are reached. These outcrops extend in long lines over the hills, and mark very clearly the course of the beds, conforming generally to the inclosing stratified formations, probably of Palæozoic age. These rocks are somewhat obscure, but there are large outcrops of limestone without much alteration. This, in places, appears to be the adjoining rock, at others the wall-rocks are porphyry, and at others apparently a quartzite and a fine-grained felsite.

The beds of iron-ore are from 10 to 100 feet and more in thickness, and some of the outcrops extend unbroken continuously for 1000 feet and more. It consists chiefly of magnetite and hematite,

and it generally shows distinct planes of structure parallel with the walls, this structure being marked by the lines of rift, and by the presence of included minerals in layers. Ages of weathering and disintegration have left enormous blocks and accumulations of ore on the hillsides below the outcrops. The flat surfaces of such blocks frequently exhibit beautifully perfect octahedral crystals, from one-quarter of an inch to two inches in diameter, covering sometimes a square yard of surface. Cavities lined with crystals are common. Portions of the ore exhibit magnetism and polarity in a remarkable degree, being true lodestone, stronger than any I have before seen in this country.

The weathered surfaces of the ore are generally coated by a most lustrous glossy black scale, apparently a mixture of oxides, and like the coating artificially formed in the Bower-Barff process.



Section of Outcrop of Iron-Ore.

The associated mineral is chiefly apatite, in small and in large crystals, but generally distributed in layers and sheets parallel with the walls. It is usually in distinct hexagonal prisms, often tapering to a point and arranged radially, forming stellate groups, being in divergent aggregations of blade-like crystals in color, white-grayish and with shades of red and brown. This description of the form of aggregation applies particularly to the bed called the Great Western. There are layers of ore of considerable thickness, apparently free from apatite, and probably such layers are without phosphoric acid.

As the Great Western outcrop is well defined and characteristic,

I annex a pen-sketch cross-section, which shows also a second bed lying parallel with the first.

The top of this outcrop is about 225 feet above the base of the hill of which it forms the crest. At one end of the bed it gradually thins out to a mere street with, at last, a few isolated crystalline bunches of magnetite in the midst of a bedded prolongation of the apatite crystals, some of which were found quite clear and transparent, with a straw-yellow tint. The iron-ore thus thins out and the phosphate of lime is prolonged beyond it. The common association of apatite with iron-ore is interesting. We have it abundantly on Lake Champlain in the old Sanford ore-bed and others; also in New Jersey, in connection with some of the ore-beds; at the Iron Mountain in Missouri, and again in the beds of Southern Utah.

For the composition of the ores I refer to the analyses of the samples taken by Professor Maynard, which will be communicated by him.

The variety in the ores in the many different beds justifies the belief that excellent mixtures can be made.

These beds are well situated for working, and are capable of yielding an enormous supply of iron for generations to come. Their extreme distance from water-transportation is, of course, a great disadvantage, for the cost of transportation to the great markets must always be heavy. But for the supply of the central portions of our great railway system of the Rocky Mountain region it certainly has the advantage of less mileage for rails than Pennsylvania, Ohio, or even Missouri. There is besides a considerable market for bar-iron throughout Utah and the adjacent territories. If the government could establish works at these great deposits, the Mormon problem would soon find an industrial solution without animosities or bloodshed.

The coal-supply is the most important and, perhaps, doubtful feature of such a possible enterprise; but there are large deposits back of Cedar City of a long-flame secondary (probably Cretaceous) coal. It is no doubt a good gas-producing coal, but its coking qualities have not yet been satisfactorily ascertained. A few thousand dollars expended by our Geological Survey in a survey of that region would give us important and much needed information.

### Discussion.

G. W. Maynard, New York City: Concerning the ores and fuels spoken of in Prof. Blake's paper, I am able to add the following analyses made for me by Mr. Andrew S. McCreath.

| Name of ore. | Metallic Iron. | Phosphorus. |
|---|---|---|
| Armstrong, | 63.925 | 0.226 |
| Adams, | 58.675 | 0.214 |
| Smith (East Side), | 59.625 | 0.032 |
| Smith (West Side), | 61.425 | 0.265 |

The Southern Utah coals have the following constitution:

| | Cedar City. | Castledale. |
|---|---|---|
| Water at 212° F., | 3.502 | 3.426 |
| Volatile matter, | 43.663 | 42.814 |
| Fixed carbon, Sulphur, | 43.108 | 47.810 |
| Ash, | 9.727 | 5.950 |
| | 100.000 | 100.000 |
| Coke, | 52 835 | 53.760 |
| Color of ash, | Pink gray | Reddish gray |

The Cedar City coke is quite coherent and hard; the Castledale much less so. An analysis of Cedar City coke is as follows:

| | |
|---|---|
| Water and volatile matter, | 1.417 |
| Fixed carbon, | 76.706 |
| Sulphur, | 5.270 |
| Ash, | 16.607 |

This is a bad metallurgical fuel, on account of its large proportion of ash and high percentage of sulphur.

---

## *RECENT FAILURES OF STEEL BOILER-PLATES.*

BY WILLIAM KENT, M.E., NEW YORK.

A MOST startling, and as yet unexplained, failure of steel boiler-plates, in two different sets of boilers, is reported in a paper by Arthur J. Maginnis, published in the London *Engineer*, December 11th, 1885, and reprinted in the *American Engineer*, January 14th, 1886. The facts of the case, as condensed from Mr. Maginnis's paper and from a number of letters in the subsequent issues of the *Engineer*, are as follows:

1. The material used for two different sets of boilers on two different steamers, each set consisting of three circular boilers with horizontal steam-chests, passed all tests required by the Board of Trade

and Lloyds. The work was regularly inspected by the Surveyors of both these Boards. The furnaces, after being welded, were carefully annealed.

2. The material stood, without the slightest defect, the ordinary work of the boiler-shop, including welding.

3. Each set of boilers worked most satisfactorily at sea for a period of two-and-a-half years, after which they exhibited signs that a complete change had taken place in the nature of the steel.

4. The steamers were in the trans-Atlantic and colonial trade. Special attention was given to scaling, and the ordinary precautions were taken to insure proper treatment of the boilers in service.

5. The signs of failure were first on Steamer No. 1, an extensive crack in one of the combustion chamber-plates, about two feet six inches long, one-eighth inch open at the top, and one-sixteenth inch at bottom; the crack occurred spontaneously about three weeks after the boilers had been blown down, and at the time no work was being done except the usual scaling.

In the case of Steamer No. 2, when the boilers had reached the same period of work as those on Steamer No. 1, a crack two feet three inches long occurred in the plate in the combustion-chamber corresponding to the first one, thirteen days after steam had been let down. The other plates of this chamber were then tested with blows from a seven-pound hammer, and three of the other similar plates were cracked; about this time, also, small cracks were found occasionally in various parts of the boiler between the rivet-holes. Three months later the next crack occurred on Steamer No. 2; and about the same time on Steamer No. 1, a few days after steam had been shut off, an extensive circumferential crack over two feet long took place in one of the wing-furnaces with an alarming report.

6. When testing the result of striking the cracked portions of one of the plates with an ordinary sledge-hammer, the first blow extended one of the cracks about four inches, leaving only two and a-half inches more of solid plate; this remaining portion was then hammered flat down, and again straightened without in the least extending the crack. On similarly testing the second plate the same thing happened, the plate in the line of the crack being hammered down flat, and then straightened out without extending it in the slightest degree, but on the other hand another piece of the same plate was struck one blow, and snapped off like glass.

7. The boilers were thereupon condemned, and new steel boilers ordered to replace them. The results of breaking up the old boilers

were, indeed, startling; upon knocking off the rivets on the connecting-pipes, between the boilers and the steam-chest, after a few blows it was discovered that the pipes were cracking in all directions, and to such an extent eventually that not one of the nine connecting-pipes from No. 2 Steamer came off whole; then after the chest had been removed from one boiler a portion of one of the pipe-flanges was being wedged from the boiler when the shell-plate suddenly cracked for about ten inches from the opening. Soon after this, when the boiler-shell was reached, one of the butt-straps cracked almost right across between the rivet-holes. "Later on, when the furnace and front-plates were started upon, a general smash was experienced, the front-plates cracking and starring, and the flanges breaking off. The furnaces at the same time acted in just the same manner, the cracks going through the rivet-holes to such an extent as to allow the ends to come off whole, and so form hoops for the lads to play with in the meal-hour." One of the plates of the upper shell, after the rivets had been cut out, was turned over and allowed to fall on the ground, and the shock broke the plate across the center.

8. The test records of the plates before leaving the works show results as follows: Forty tests in all are given by Mr. Maginnis. The thickness of the plates tested varied from 0.41 inch in the steam-chest plates to 0.74 inch in the shell-plates; the tensile strength from 58,332 to 68,095 pounds per square inch; the greatest elongation was 27 per cent. in ten inches, and the lowest 19¾ per cent. An inspection of these forty tests shows that eight plates were between 58,000 and 60,000 pounds tensile strength; twenty-four plates were between 60,000 and 64,000 pounds; and eight plates between 64,000 and 68,095 pounds; twenty plates showed elongation between 19¾ and 22 per cent. in ten inches; eleven plates between 22½ and 24½ per cent.; nine plates between 25 and 27 per cent. Pieces were cut from the cracked plates of the combustion-chambers in the boilers, and the tests show the following results:

| Steamer No. 1. | Four Tests. |
|---|---|
| Tensile strength, . | 103,430, 106,400, 90,720, 104,026 pounds. |
| Elongation, . . . | 8, 7.75, 13, 15 per cent. |

Fractures all fine crystalline.

| Steamer No. 2. | Seven Tests. |
|---|---|
| Tensile strength, . | 58,026, 54,298, 56,837, 57,120, 60,122, 60,032, 56,851 pounds. |
| Elongation, . . . | 15, 24 5, 22, 17.25, 26, 26.75, 8 per cent. |

Fractures all "fibrous, silky, fine."

Chemical tests from the cracked plates, taken from the combustion-chamber, are as follows:

| | Steamer No. 1. | Steamer No. 1. | Steamer No. 2. |
|---|---|---|---|
| Carbon, | .125 per cent. | .125 per cent. | .175 per cent. |
| Silicon, | .005 " | .018 " | .018 " |
| Manganese, | .320 " | .530 " | .370 " |
| Sulphur, | .051 " | .043 " | .045 " |
| Phosphorus, | .060 " | .061 " | .068 " |

The chemist reports that "the material, chemically speaking, is not at all objectionable, being of good average quality."

*Theories Given to Account for the Failures.*

1. *Internal Strains.*—Editorial in the *Engineer*, December 11th: "Our theory is that the plates had initial stresses operating in them and tending to cause fracture. . . . . There is every reason to believe that these stresses bear a distinct relation to the size of the plates. . . . . The reason why steel fire-boxes succeed in American locomotives and not with us, it is said, is that small plates are used in the States and large plates here. We try to make a fire-box with three plates; they do not hesitate to use seven in the United States. If our view be correct, and every large plate of steel may have heavy initial stresses existing within it, it will be seen that the ordinary system of testing small samples cut from the plate gives but a faint indication of the true strength or quality of the metal."

2. *Homogeneousness.*—Same editorial: "It is the fibrous nature of iron that mainly contributes to give it a trustworthiness which is not possessed by steel. The phenomena of cracking are given to all homogeneous materials; take, for instance, earthenware."

"L.," a correspondent of the *Engineer* of December 25th, says: "The fracture of steel boiler- and ship-plates is due, not to the defect in the metal, but to the homogeneity of the metal. So long as steel is homogeneous so long will fractures such as that of the boilers of the 'Livadia' and many others occur. *Nothing that the steel-maker can do will prevent their occurrence, because the steel-maker has nothing to do with the immediate cause of failure.* This statement is to be taken, of course, within limits, that is to say, that the steel must be free from notable percentages of sulphur and phosphorus." . . . .

"It is a special characteristic of all homogeneous bodies submitted to stress *that if they once begin to give way the process will be continuous until it is complete*, provided the stress be kept up. If this

proposition be true, a crack, however small, once developed in a steel plate, must continue to extend if the stress is maintained until fracture is complete." [It seems to the writer that this is completely disproved by the test of the cracked plates given by Mr. Maginnis, paragraph No. 6, above.]

"L." continues: "In glass we find the analogue of steel. It is homogeneous, possessed of great elasticity, and considerable strength; it differs from steel more in degree than anything else."

3. *Crystallization.*—Editorial in the *Engineer:* "Crystallization is a very mysterious phenomenon; how much crystallization had to do with the failure of these plates we cannot pretend to say."

Editorial in the *Engineer*, January 1st, 1886: "So far as can be known, the unexpected fracture of steel plates is due to the spreading of extremely fine initial cracks, and this can only be controlled efficiently by giving the plate a fibrous structure."

4. *Internal Deterioration.*—"Iron" writes to the *Engineer*, January 1st, 1866: "The cracking of the neck pieces, and especially of the shell-plate at the top of the boiler, would seem to indicate that the mere heat of the steam is sufficient to produce deterioration after a time. This deterioration of homogeneous substances through repeated alternations of temperature is nothing new, but it has not often been pointed out that final rupture occurs usually some time after the cause of deterioration has ceased to operate."

5. *Large Plates.*—Same writer: "The internal strains tending to tear to pieces large steel plates must of necessity be greater and more dangerous than those in smaller ones. A cast-iron floor-plate three or four feet square will stand well enough, but a similar plate, nine or ten feet square, will, even if cast successfully, not be long before it splits in two of its own accord."

6. *Bessemer Steel Untrustworthy.*—Editorial in the *Engineer*, January 1st, 1886: "No advance whatever has been made during the last ten years towards the elimination of the treacherous characteristics of the metal; indeed, there is some reason to fear that steel is not so good as it was. It would be interesting to know why Siemens steel has come to be regarded by engineers and boiler-makers as better in the sense that it is more trustworthy than Bessemer steel, and it may yet be that the product of the converter will be mainly devoted to rails, tires, and axles, while boiler-plates will be produced only by the Siemens process."

7. *Insufficient Work on Ingots.*—"Basic" writes to the *Engineer:* "The Weardale Company enjoyed a high reputation for their steel

plates. In an evil hour they undertook to make heavy plates, with results stated by Mr. Maginnis. These plates were made from ingots not more than eight or nine inches thick; there was not a hammer nor a cogger in the place fit to deal with anything bigger. In consequence the steel was never worked as it ought to be. Messrs. Jack, of Liverpool, made the boilers, and over 40 per cent. of all the plates supplied failed to pass the test, and were returned to the makers. The wonder is not that the boilers gave way, but that they held out for two and a-half years. To assert that such stuff represents steel is nonsense; putting it in the market at all is a wrong to other steel makers. The Weardale Company now make as good a steel as there is in the market."

8. *Improper Manipulation of Plates.*—F. B. DuPre, manager of the Weardale Coal and Iron Company, writes to the *Engineer* of December 25th: "The plates were made by the Weardale Company in 1880; the steel was made in small two-and-a-half ton converters by the Bessemer acid process. . . . . We for years manufactured steel in the same Bessemer converters, and although a large quantity was used for boiler-plates, this is the only serious complaint that we ever received. . . . . After they left Tudhoe Works many things may have been done to damage the structure of the plates, and we must, I submit, seek for the cause of failure in some defect of the manipulation of the plates by the engineer, or in the subsequent treatment of the boilers when in the vessel."

William Metcalf, of Pittsburgh, writes to the *American Engineer* of January 21st: "It looks as if these boilers had been made of steel that was not uniform in character in the several sheets, or as if it had been made by men who were used to working iron, and who had not been trained to work steel. The sheets were probably flanged, welded, etc., at a good iron heat; the grain was raised, internal destructive strains were set up; the work was not afterwards properly annealed; the steel, what there was of it that was good originally, was weakened, and under the stress of service the boilers went to pieces." [Mr. Maginnis's paper, however, states that the furnaces, after being welded, were carefully annealed, according to the special instructions of the Board of Trade, the work throughout being regularly inspected by their surveyors and those of Lloyds' Register. The material had also been periodically tested at the manufactories by both of these Boards.]

The discussion caused by the failure of the plates in question has

brought out a number of interesting facts, of which the following may here be noted:

First, it seems that iron, as well as steel, is liable to mysterious failures. Mr. John Harrison writes to the *Engineer* of December 25th that thirty-seven years ago the steamer Leipzic, built at Hull, had her boiler-furnaces cracked in the same way as those described in Mr. Maginnis's paper; the iron was not good, and had to be renewed.

Editorial in the *Engineer* of January 1st, 1886: "The failure of certain ship-plates and angles in the North . . . . such failures have been comparatively numerous, and the treacherous plates and angles have been in all these recent cases made of basic steel. . . . . Messrs. Bolckow, Vaughan & Co. have, in consequence, stated that they will make no more basic plates or angles, and Lloyds' Committee have resolved not to class any ship built of basic steel, and have withdrawn their inspectors from yards where basic steel is used. . . . . Lloyds' will permit boilers to be made of it, but only under certain stipulations; its strength must not exceed about twenty-four tons to the square inch."

Same editorial: "Mr. Parker, chief engineer surveyor at Lloyds', is now conducting a series of experiments with a view to solving the steel problem, and ascertain why steel plates break. To this end he has subjected steel plates of all kinds to the worse possible treatment, such as heating one corner while the rest is kept cool, making a hot fire on the center of a plate while a hose played on the metal outside the heating circle, and so on, but up to the present he has not succeeded in getting a plate to crack."

It does not seem to the writer that the theories quoted above are sufficient to account for the failure of the steel plates in question. The "internal strain," "too large plates," "too small ingots," "too little work," "homogeneity," and "crystallization" theories all seem to be answered by the facts that internal strains must exist in all steel plates which have any work done on them while in a cold state, even if subsequently annealed, unless the annealing heat and the rate of cooling are uniform throughout the plate; that very much larger plates than those used in the two steamers are now in common use; that thousands of plates have been made of small ingots; that other thousands have had too little work put on them; that all steel plates are supposed to be homogeneous, and all are supposed to be liable to crystallization; and yet that not one nor all of these causes combined is sufficient to make the chance of sudden fracture of any

plate as much as one in ten thousand; and that of all the hundreds of thousands of steel boiler-plates which must have been put in service in the past twenty-five years, many of which have been subjected to most severe usage in the boiler shop as well as in the boiler itself, there is not on record another single case in which a steel boiler went to pieces while it was not under pressure, and after two and a half years of service. The startling coincidence of the peculiar fractures in six boilers, three on one vessel and three on another, in both vessels after two and a half years' use, would indicate, if we knew nothing else about their history, that the steel in these two boilers was of the same quality, and that quality very different from that common to steel boiler-plate in general; but when we know that the steel came from the same works, and the boilers were made by the same maker, the conclusion is irresistible, that the steel was very different, in some one quality or other, from all other boiler-plate steel of which we have any knowledge, or else that the treatment in the boiler shop was something very different from that to which steel boiler-plate is usually subjected. The last supposition is so highly improbable that we are narrowed down to the one conclusion that there was something the matter with this particular lot of steel which differentiates it from all ordinary boiler-plate steel.

One paragraph only in all the newspaper communications concerning this failure seems to favor this view—the letter of "Basic," above quoted. "Messrs. Jack of Liverpool made these boilers, and over 40 per cent. of all the plates supplied failed to pass the tests, and were returned to their makers." If 40 per cent. of all the plates sent were rejected, even under the comparatively easy tests of Lloyds and the Admiralty, and out of 40 tests recorded of those accepted 20 per cent. would have been rejected for too high tensile strength on the specifications of the Pennsylvania Railroad for fire-box steel, and 75 per cent. would have been rejected for insufficient ductility on the original specifications of the Government for the boiler-plates for the U. S. cruisers, it must be conceded that the steel was a "bad lot."

To charge the failure of this steel to the treacherous nature of steel in general, and to say that nothing the steel-maker can do will prevent such failures, is both illogical and unscientific. If the failure of steel boiler-plates were a matter of everyday occurrence, we might justly call steel a treacherous material, but when the plates that break are not one in ten thousand of the plates that are made, it would be more logical to say that steel is the most trustworthy of all metals, and when a fracture does occur, it would be more scientific to say

that there must be some unusual cause for it, and to attempt to discover that cause, than simply to charge it to the "total depravity" of steel in general, and say it cannot be prevented.

But after reaching the conclusion that the steel was bad, we are as much in the dark concerning it as before. Why was it bad? and if bad, why did not the tests show the fact, so that it would have been prevented from going into the boilers? The 40 tests do not of themselves prove that the steel was bad; for steel showing far worse results in the testing-machine has repeatedly gone into boilers in the United States, some of it into externally-fired boilers on the Ohio River steamboats, licensed to carry 170 pounds steam pressure, the plates bent cold into shells of boilers only 42 inches diameter, rivet-holes punched, and the plates not annealed either before punching or after it, and the boilers presumably in service far more severe than that to which internally fired marine boilers are ever subjected, and yet no explosion, no mysterious fracture, but on the contrary the most complete satisfaction to the owner and user.

The chemical analyses do not reveal the cause of the difficulty, for while the phosphorus percentage is higher than is now considered proper for the best quality of boiler-plate steel, there are vast quantities of boiler-plates in use with a much higher percentage.

Since the data we have concerning these steel plates are not sufficient to enable us to determine with certainty the cause of their failure, we may consider possible causes other than those already cited. The following theories are offered as a possible explanation:

1. The chemical analysis of the steel (supposing it to be correct as far as it goes) is not complete, and the steel may have contained other elements in sufficient quantity, which by themselves or in combination may have caused the steel to become brittle in service. Elements that might be looked for in this connection are copper, cobalt, nickel, arsenic, tungsten, vanadium, and oxide of iron.

2. Want of homogeneity of the steel, due to its imperfect mixture, and especially to the imperfect mixture of the carbon and manganese of the recarburizer with the mass of the molten steel. Such a want of homogeneity, it is not impossible, may take place in the Bessemer process when working with $2\frac{1}{2}$-ton converters. We have not the facts concerning the method of recarburizing adopted in the manufacture of the steel in question, whether the ferro-manganese was added in the solid or the liquid state, but in either case it may not have been thoroughly mixed through the mass of metal before cooling of the ingot. If it was added in the solid state, it would be like

adding salt to soup; time and stirring are necessary to make a homogeneous mixture. If added in the liquid state, it would be like adding a little molasses to honey; it would take a good deal of shaking to make the two mix thoroughly.

Suppose the metal thus imperfectly mixed were rolled into plates, the defective mixing would appear in the plate as hard spots or streaks throughout the mass, which, on account of their amounting to but a small percentage of the mass, would be likely to escape discovery by ordinary testing-machine methods. Finding hard spots in steel is a matter of not infrequent occurrence with steels higher in carbon than boiler-plate, and the reason they are not so often found in low-carbon steel like boiler-plate, is probably that in the latter the amount of recarbonizer used is so small that the chances of finding any portion of it unmixed with the mass are very slight.

But how would this want of homogeneity cause the cracking of the boilers after two and a half years of service?

This can only be answered by another theory. Suppose that the want of homogeneity should consist in the plate being formed of successive layers or streaks of different composition; thus one layer might be composed of .10 carbon steel, the next a thin streak, microscopically small, of oxide of iron, then another streak of imperfectly diluted ferro-manganese containing say 1 per cent. carbon and 20 per cent. manganese. Such a mass would have two characteristics, one or both of which might cause gradual disintegration—the first physical, the second chemical.

*First.* Each of the layers or streaks would have a different rate of expansion and contraction from that of its neighbor. The alternate heating and cooling would cause internal strains in opposite directions, and the continued repetition of these strains would act like the continuous repeated and reverse strains in a car-axle, which, as well known, tend to put a period to its "life." Two and a half years of such service in a boiler might be sufficient to cause molecular disintegration.

*Second.* If such a mass of steel were kept at a red heat for a week, we know from our experience with the phenomena of cementation, case-hardening, annealing in oxides, etc., that the mass would tend to become homogeneous, chemically; in other words, the oxide of iron streak would unite with the carbon in the adjoining streak; the high carbon streak would tend to lose its carbon, and the low carbon streak to gain it. The tendency to equalization of carbon in iron and steel is universal. Whenever carbonized iron is heated in

presence of oxide of iron, the carbon tends to leave the iron; whenever iron is heated in presence of carbon, the carbon flows into the iron. This action is more rapid, the higher the temperature. May it not be possible, that, at low temperature, say, 300° to 350° F., the temperature of steam in the boiler, the tendency will also become active, and the chemical reactions between oxide of iron and carbonized iron and manganese may go on slowly, requiring, say, years to accomplish what would be done in a week at a red heat? The probabilities are entirely in favor of such action taking place, and, if it does take place, it is scarcely conceivable that some such phenomenon as "opening of the grain" of steel, which is caused simply by heating, will not take place at the same time.

There are analogies in the various alloys of copper, which appear to favor the view that heterogeneity of constitution may lead to disintegration. In the discussion of Professor Egleston's paper at the Montreal meeting in 1879, "The Law of Fatigue and Refreshment of Metals," vol. viii., p. 398, instances of the disintegration of brass are presented, and similar instances are given in Professor Egleston's paper before the American Society of Mechanical Engineers (*Transactions American Society of Mechanical Engineers*, vol. v., p. 140). In this latter paper, he says: "Under certain conditions, likely to happen frequently in anything made of iron and steel, the uncombined carbon in iron and steel would become combined and the metal would become brittle." "I have seen similar defects not only in iron and steel, but also in copper, tin, brass, and in almost every other commercial alloy." "Very frequently, alloys composed of different metals, when fatigued, *would separate, each metal taking its own rate of flow*, and separating from the original mass in such a way as frequently to lead to disastrous results." "This flow of the metal may be made to take place either by pressure or by heat, and is usually called, in the brass works, 'the starting of the zinc.'"

I conclude with a re-statement of the theory which seems, to me, most likely to be the correct one to account for the failure of the steel plates referred to, and hope it will lead to discussion of the question whether it should not be taken as a "working hypothesis" in our future studies of soft steel, at least until it is disproved by an accumulation of facts against it. *The most probable cause of the so-called "mysterious failures" of steel boiler-plates is not their homogeneity, but their heterogeneity; and the latter is caused by imperfect mixture of the recarburizer with the mass of molten steel before casting.*

## Discussion.

Professor T. Egleston, New York City: The paper which has been read on the failure of these boiler-plates reminds me very much of the discussions which took place when steel rails were first introduced, and of the anxiety that was felt by all persons lest for some unforeseen reason they should do a great many things that they never have done and probably never will do. I do not propose or expect to be able to solve the question of the cause of the failure of these boiler-plates, but simply to call attention to a few facts which were, at the time that they occurred, as thoroughly inexplicable as these, and also to recall some others which are not stated in this discussion.

When steel rails were first used, the German and French governments found it absolutely indispensable to put in their contracts, and also to force their employees, to lift rails from the ground and to place them wherever they were to be placed without allowing them to fall; and it was specified in every contract that in unloading the rails they should be slid on skids to the points where they were to be used, and then treated gently. The idea seemed to prevail that steel rails either were or became extremely brittle from some unknown cause, and this was justified by many facts which occurred in this country, notably by the accident which happened to a large lot of rails on the Lehigh road, which were run into by a train which ran off the track, and subsequently were found to be quite useless. I have very little doubt, and I said at the time, that I thought that the shock which produced the crystallization which made these rails brittle, could only be accounted for by the fact that the rails had been finished too cold, and were subject to a series of internal strains which the shock brought up to such a condition that a solution of continuity became easy, so that the rails were either broken by that shock or became so brittle that they were easily broken afterward. This was in the first part of our history of the treatment of large ingots. Every year of the working of steel in large quantities shows how rudimentary our knowledge of the treatment of large pieces of steel was in those early days. Ingots of a ton were then uncommon, while ingots of 25 tons are not now very uncommon, and ingots of 100 tons of steel are sometimes made.

I have had occasion recently to allude to the fact that it was absolutely necessary in large masses of this kind to provide for two things. One of these is to obviate the difficulties which arise from

having a center in a very large piece, which simply adds to the weight and not to the strength;* the other is, that it is necessary that these large pieces should be cooled from the inside out as well as from the outside in. In very large ingots, not only internal strains are set up by the unequal cooling, but there is a liquation of the materials, which may, in the case of the carbon, sometimes rise as high as one-quarter of one per cent. A careful investigation which I made upon this subject, some years ago, showed that this liquation took place in small as well as in large ingots. The larger the ingot the more essential it is that the heat should be the same on the inside as on the out, and this can only be effected by time. The ingots are often hotter in the inside than on the outside, and are sometimes even liquid. I have many times seen ingots where the outside crust was so thin that the liquid from the center broke away and gave a hollow ingot, or where the outside was at a black heat while the inside was still red. The reverse may often happen, that when the ingot is reheated it may simply be red on the outside without being much above a blue temperature in the interior. The treatment of steels under these conditions can only be most unfortunate. It is pretty well known now that the critical temperature of iron and steel is at the blue heat, a temperature of about 700 or 800 degrees, and that at this temperature the metals are brittle. I believe it is also true that when metals are worked near to this temperature internal strains are set up. Nothing can be worse for a large ingot than its treatment when it is not thoroughly heat-soaked, that is to say, when it is not exactly of the same temperature on the outside as on the inside; after it is treated and got into form it should be cooled slowly. The proper treatment of a piece of steel would be never to allow it to get cool until it reaches the final stage of its manufacture; and this is the case in some of the best works in Europe where they treat large masses of steel. When, however, they are heated and appear to be at a workable temperature upon the outside, they should be left so long in the furnace as to make it certain that the interior will be exactly of the same temperature as the outside. I do not say that this was the cause of the failure in the working of these basic plates. I have recently made some investigations on the working of the basic process,† and spent many

* Transactions of the American Society of Mechanical Engineers, Nov., 1885.

† School of Mines Quarterly, vol. vii., p. 49; Transactions of the Institute of Mining Engineers, vol. xiv., p. 455; Transactions of the Institute of Mechanical Engineers, vol. vi.

weeks in the works in order to study the processes employed, and have noticed that under certain conditions the men were careless about the management of the *process*, and that improper ingots were sometimes rolled. In the hurry to make a large output, ingots are sometimes sent to the mill when they are not only of improper chemical but mechanical composition. It is not usual to hammer ingots,—they are generally rolled,—but I have often seen an objectionable ingot rolled at a temperature so cold that I should scarcely be willing to accept the plate. It does not add, I am sorry to say, much to our confidence to conclude that, with our present knowledge, it is impossible to ascertain beforehand what the condition of the strain is in the interior of the iron and steel without making a careful microscopic examination; and it is not certain that this would always reveal the condition, though I believe there are peculiarities in the structure which could be shown by the microscope. The internal strain, unfortunately, does not act upon the metal like the scratch upon a Rupert's drop, which sends it to a thousand slivers; but we wait for such disasters as occurred in the early days of steel works, and such disasters as might have been caused by these boilers had they gone to pieces at sea. The mere fact that they broke to pieces under slight blows and strains shows that they must have been under great strain. For myself, I am entirely dissatisfied with the present method of testing, as well as with the testing machines which are used; and I believe that engineers and others using structural materials will have to give serious attention to this matter of testing before very long. It is a much more serious matter than we generally think. I was myself witness of one accident to one of the Cunard steamships, which went upon the shore, a slight bump requiring 25 feet of her plates to be taken off. This same vessel was subsequently run into by another steamer, and 35 feet of her stern-plates above the water-line seriously dented. These plates were all taken off and all but one were straightened cold. They tried to straighten that one plate hot, but it went to pieces like glass.

I think, probably, not being familiar with the analysis and the general condition of the iron in these boilers, but simply judging from my previous knowledge of such matters, that the cause of the fracture is more likely to have been physical than chemical.

## *SOFT STEEL FOR BOILER-PLATES.*

BY ALFRED E. HUNT, PITTSBURGH, PA.

THE technical papers of the last few years give numerous instances of serious failures by cracking or rupture of soft steel boiler-plates, many of which have satisfactorily passed the rigid inspection and tests required by both Lloyds' Register and the Board of Trade in England. I speak of the inspecting department of Lloyds' and the Board of Trade, for we do not begin to have as systematic and intelligent work regularly done in this country as is done by these institutions in England.

Tension-tests of this steel have given from 55,000 to 65,000 pounds per square inch tensile strength, with from 20 to 30 per cent. elongation in 8 inches. Chemical analyses have shown the steel to contain from 0.12 to 0.15 per cent. carbon, from 0.25 to 0.40 per cent. manganese, and from 0.03 to 0.05 per cent. phosphorus. All of these tests are considered normal, and, in the words of one of our members, "boiler-plates with these qualities ought not to fail."

There are, however, several causes of failure in soft steel plates which, although the writer does not presume to ascribe to them, or either of them, any particular instance, are still dangerous, and ought to be guarded against much more carefully than in usual present practice.

These causes are:

1. The hardening property of all steel.
2. Insufficient work from the ingot to the finished plates.
3. Temporary fiber in certain steels.
4. Internal strains caused by unequal work upon the material.

*Hardening.*—The writer, in a paper read before the Institute in October, 1883,* made the statement that soft steel, no matter how low in carbon, would harden to a certain extent upon being heated red-hot and plunged into water, and that it hardened more when plunged into brine and less when quenched in oil, and gave the results of one experiment, merely as an illustration of many which had all confirmed the statement made.

The illustration was a heat of open-hearth steel made by the writer, of 0.15 per cent. carbon and 0.29 per cent. of manganese, which gave the following results upon test-pieces from the same $\frac{1}{4}''$-thick plate.

* "Some Notes and Tests of an Open-hearth Steel Charge made for Boiler-plate." —*Trans.*, vol. xii., p. 311.

| | Maximum load. lbs. per sq. in. | Elongation in 8 inches. Per cent. | Reduction of area. Per cent. |
|---|---|---|---|
| Unhardened, . . . . | 55,000 | 27 | 62 |
| Hardened in water, . . . | 74,000 | 25 | 50 |
| Hardened in brine, . . . | 84,000 | 22 | 43 |
| Hardened in oil, . . . . | 67,700 | 26 | 49 |

A similar steel boiler-plate, made by the writer, of 0.18 per cent. carbon (made higher in carbon in order to get 60,000 pounds per square inch maximum load in $\frac{3}{4}''$-thick plates), gave in a $\frac{1}{4}''$-thick plate the following results:

| | Maximum load. lbs. per sq. in. | Elongation in 8 inches. Per cent. | Reduction of area. Per cent. |
|---|---|---|---|
| Unhardened, . . . . | 64,570 | 30 | 60 |
| Hardened in water, . . . | 91,219 | 25 | 46½ |
| Hardened in brine, . . . | 99,300 | 16 | 34 |
| Hardened in oil, . . . . | 90,300 | 27 | 50 |

Similar results have been obtained by the writer from a considerable number of samples from various manufacturers of boiler-plate.

While the ductility of such hardened steel does not decrease to the extent that the increased tenacity would indicate, and is much superior to that of normal steel of the high tenacity, still the greatly increased tenacity after hardening indicates that there must be a considerable molecular change in the steel thus hardened, and that, if such a hardening should be created locally in a steel plate, there must be very dangerous internal strains caused thereby.

Such hardening could often occur, especially in marine work, liable to ship a heavy sea on heated boilers, or in encrusted boilers, where a stream of cold feed-water comes suddenly upon locally-heated plates, or even back at the rolling-mill, where the plate has been allowed to be suddenly or unequally cooled after rolling.

Mr. W. Parker, of Lloyds' Register, in a paper read about a year ago before the Institute of Naval Architects of Great Britain, pointed out the dangers of the use of boiler-plate too high in tenacity, on account of the extreme danger of the metal becoming tempered by the heating and cooling to which the plates may become subjected. He said that his "investigations have clearly pointed out that engineers have been drifting towards the use of an unreliable material, or, at all events, a material which is too near the verge of danger to be pleasant with steam-boilers," and that he would urge, in order to remedy this growing evil, that a lower tensile strength be allowed for thick plates and that a temper-test should be insisted upon with

every thick plate, and the practice of using such enormously large plates should be discouraged.

*Insufficient Work.*—Soft steel ingots, made in the ordinary way for boiler-plates, have only from 10,000 to 20,000 pounds tensile strength per square inch, an elongation of only about ten per cent. in eight inches, and a reduction of area of less than twenty per cent. Such ingots, properly heated and rolled down from ten inches to one-half inch thickness, will give from 55,000 to 65,000 pounds tensile strength, an elongation in eight inches of from 23 to 33 per cent., and a reduction of area of from 55 to 70 per cent. Any work stopping short of the above reduction in thickness ordinarily yields intermediate results in its tensile tests. .

All engineers would agree that the steel of the original ingot, with its tensile strength of only 20,000 pounds, would be unfit for boiler-plate. Just where the safe limit in the minimum amount of work or reduction in thickness from the ingot to the plate is, has not been definitely established in rolling-mill practice. Undoubtedly the point varies with different soft steels, and is dependent upon the porosity of the ingot and the readiness with which the walls of the blow-holes weld up, or at least knit together when compressed. Experiment has, however, proved, in so many instances as to make it safe to generalize upon the data, that the ordinary boiler-plate steel of the open-hearth furnaces of to-day, cast into bottom-poured ingots of ten inches thickness, requires to be rolled down to at least $\frac{1}{2}$-inch thickness, and, in the majority of cases, to $\frac{3}{8}$-inch thickness, in order to combine in the tensile tests of the plates the greatest amount of tenacity together with the greatest amount of ductility. Many of the boiler-plates of to-day do not get anything like this work, although the practice is greatly improving every year at all the mills in this respect.

In the writer's experience, much of the boiler-plate which in the $\frac{1}{4}$- and $\frac{3}{8}$-inch thick shell-plates stands 55,000 to 60,000 pounds per square inch tensile strain will, in the $\frac{5}{8}$- and $\frac{7}{8}$-inch thick heads of the same steel, stand only 46,000 to 50,000 pounds per square inch. In order to insure the higher tensile strength in the thick steel, resort has been taken to a higher-carbon metal. This is to run from the Scylla of insufficient work to the Charybdis of a metal that will temper dangerously.

Mr. Thomas Turner, in writing to the London *Engineer* on the subject of Mr. Parker's paper, above referred to, says that the only way out of the difficulty of using such high carbon in thick steel

plates seems to be that the plate-makers should have machinery capable of working from thicker ingots and dealing with them as effectively as with the smaller ones, thus giving to thick plates the same relative amount of working. He then gives a table of results obtained by him from his Corngreaves open-hearth steel. An ingot of 9 inches thickness was rolled down to 3 inches; a piece of the 3-inch plate rolled to 2 inches; the 2-inch plate to 1 inch; and the 1-inch to ½-inch. Test-strips were taken of each thickness of this same ingot of steel, with the following results:

| | Maximum load. lbs. per sq. inch. | Elongation in 8 inches. Per cent. |
|---|---|---|
| 3-inch plate, . . . . | 49,460 | 16.4 |
| 2-inch plate, . . . . | 52,416 | 30.4 |
| 1-inch plate, . . . . | 54,656 | 32.4 |
| ½-inch plate, . . . . | 59,360 | 36.5 |

The writer has held, in several instances, in his inspecting work, that soft steel of less than 50,000 pounds tensile strength is dangerously wrong somewhere, either in the original quality of the metal or in the amount of work to which it has been subjected. It has been contended that steel for heads to boilers cannot be too soft, and that, because of the lower tensile strength of 48,000 pounds per square inch, therefore the metal is necessarily softer than the same metal rolled down to say half the thickness and with a higher tensile strength of 56,000 pounds per square inch, with the same or higher ductility. The very common practice of using such insufficiently-worked plates is believed by the writer to be one of the very dangerous causes of failure in steel boiler-plates.

*Temporary Fiber.*—There have been many instances put on record for both steel and iron, of material that works well in the original bar, billet, or plate, but in which just one more working or overheating will render the metal crystalline and very cold-short. In rivet-steel this dangerous peculiarity has especially to be guarded against. The writer has had in his experience several lots of rivet-rods of steel that seemed chemically to be all that could be asked of them, and would bend double without fracture, and give tensile tests of 60,000 pounds per square inch, with 25 per cent. elongation in 8 inches and 60 per cent. reduction of area, and yet, however carefully worked into rivets, they would become so cold-short and so entirely crystalline in character as to be utterly worthless.

Just what causes this peculiarity has not been shown, at least, to the writer's knowledge. In a case of a similar failure of rivet-iron, Mr. James Burden, of Troy, some years ago said he had noticed

that such results were obtained whenever he used a certain ore in the blast-furnace from which the iron was made.

Perhaps a similar cause may have produced a like effect in some of the recent "mysterious failures in boiler-plates."

*Internal Strains.*—As has been pointed out, work and flexure and hardening, each cause a marked change in the molecular tension of steel. If this action be local, there will surely be dangerous strains in the metal; and such strains have often caused it to snap as sharply and decidedly as a glass lamp-chimney in which a like condition has been produced.

The following specifications the writer would recommend to be exacted for soft steel for boilers:

### Specifications for Boiler-Plates.

The method of manufacture of the steel for boiler-plate shall be distinctly specified in the contract—whether by the open-hearth, Bessemer, or crucible process. The ingots from which steel plates for boilers are rolled shall be at least twenty times the thickness of the finished plate.

No steel for boiler-plates shall be rolled, struck with a hammer, or otherwise worked at the black heat, which is just before a red heat in daylight, or at a temperature of from 750 to 950° Fahr.

All boiler-plate must be tough, soft, ductile, and uniform in character, neutral in quality, and have a smooth surface and sound edges, and a workmanlike finish. It must be free from seams, blisters, buckles, pit-holes, or spots containing clay or other foreign substances, that may have been cast in with the steel into the original ingot or rolled into the plates from substances sticking to the hot ingots during the rolling.

The plates must be sheared true to size and out of wind, and must have at least one-half inch of scrap sheared off each of the sides, and at least two inches sheared off at both top and bottom of the plates, as rolled from the ingots. The finished plate must not have a variation of more than one and a half per cent. between the actual and the estimated weight, reckoning the specific gravity of the steel to be, according to Mr. Miller's paper, read at this session, 7.8635, which, in my judgment, is pretty nearly correct; or a plate one-quarter inch thick and one foot square must weigh $10\frac{19}{100}$ pounds.

Steel for boiler-plates shall not contain over —— per cent. carbon and —— per cent. manganese in plates of under $\frac{5}{8}$ inch thickness, nor more than —— per cent. carbon and —— per cent. manganese

in plates of over $\frac{1}{8}$ inch thickness. Boiler-plate steel shall not contain over —— per cent. silicon, over —— per cent. sulphur, and —— per cent. phosphorus. (The percentage to be filled in by contractors in their bids.)

If drillings of the steel taken from any portion of the finished material do not satisfactorily answer the chemical requirements guaranteed by the contractor, the steel of the whole charge or blow is to be rejected, unless it shall be proved that the defect was caused by the particular ingot, bloom, or plate having been "burned" in heating.

Each plate shall have plainly stamped upon it the maker's name, the guaranteed tensile strength, and the cast-number, and, after inspection, the inspector's stamp.

At least one of the plates of each different thickness, and of each heat, as rolled from the ingot, and before being cut up into smaller plates, shall have test-coupons $1\frac{1}{4}$ inches wide and 36 inches long attached, but so nearly sheared off as to be easily detached. These coupons shall be stamped with the cast-number. They shall also be stamped by the inspector for his identification before being detached from the plates; and they shall then be cut into lengths, one of 16 inches for tensile tests, and two of 10 inches each for bending.

Drillings for analyses will be taken under the supervision of the inspector from the test-strip used for cold bending.

Material to be tested shall be of the full thickness of the plate, so cut that the sectional area of the strips shall be at least 0.50 square inch, and, where possible, at least 18 inches long. Such specimens should be prick-punched lightly from end to end into 1-inch divisions, on the surface (or, preferably, on the edge of flat specimens), for the purpose of determining the elongation and marking the place of rupture or other defects in the specimen.

For such purpose the number of inches shall be reckoned from the top or forward end, as the specimen is placed in the testing-machine.

The bending of specimens may be done in a press or by means of levers or other machines, or by blows of a hammer. In the latter case, however, the hammer-blows must not strike upon the steel undergoing the flexure.

Test-specimens shall in no case be annealed, heated, hammered, forged, or otherwise treated, and shall fairly represent the quality of the material to be tested.

Complete facilities for inspection of material and workmanship must be given by the contractor. Facilities and specimens for test-

ing, and the necessary labor, shall be furnished by him without charge, when called for by the inspector.

The acceptance of any plates by the inspector at the mills shall not prevent their subsequent rejection, if found defective at the boiler-works or after their further delivery; and any such plates shall be replaced by and at the expense of the contractor.

Plates under $\frac{1}{2}$ inch in thickness shall show, in test-specimens, a tensile strength of not less than 55,000 pounds, nor more than 65,000 pounds per square inch, and shall have an elongation of at least 23 per cent. in 8 inches, and a reduction of area of at least 55 per cent., and show a silky fracture after being pulled.

Test-specimens of plates (with sheared edges well rounded with a file) $\frac{5}{8}$ inch and under in thickness, shall bend cold to an angle of 180° upon themselves without any sign of fracture. Similarly prepared strips, heated red hot and plunged into brine or into water at a temperature of less than 80° Fahr., must also bend to an angle of 180° upon themselves without fracture.

Boiler-plates of $\frac{1}{2}$ inch and over in thickness shall show in test-specimens a tensile strength of not less than 50,000 pounds per square inch, nor more than 65,000 pounds per square inch, and shall have an elongation of at least 23 per cent. in 8 inches, and a reduction of area of at least 50 per cent., and shall have a silky fracture after being pulled apart. Test-specimens of plates (with sheared edges well rounded with a file) over $\frac{1}{2}$ inch in thickness shall bend cold to an angle of 180° around a 2-inch pin, without showing sign of fracture. Similarly prepared strips, heated to a red heat and plunged into water at less than 80° Fahr., or into brine, must also bend to an angle of 180° around a 2-inch pin without showing sign of fracture.

### Specifications for Rivet-Steel.

All rivets shall be of soft pure steel of good quality. All rivet-steel shall be capable, without cracking or serious abrasion, of being heated to a good forging heat, and made up either by machine or hand work into rivets, and of again being heated to a good red heat and forged or pressed into, as in riveting, and allowed to cool; and upon being nicked and cut out of the work it is in, must show a tough fibrous structure, with no crystalline appearance. Rivet-steel shall especially be required to be neutral in character and pure in composition, tough and fibrous *after riveting*, and to flow well in riveting.

Rivet-steel should not contain over 0.15 per cent. carbon, and

must not have an ultimate strength of over 60,000 pounds per square inch, and must have an elongation of at least 25 per cent. in 8 inches, and a reduction of area of at least 60 per cent.

---

## *OPERATION OF WARWICK FURNACE, PENNSYLVANIA, FROM AUGUST 27th, 1880, TO SEPTEMBER 1st, 1885.*

BY JOHN BIRKINBINE, PHILADELPHIA, PA.

THE experience of the past five years has furnished opportunities to study and to partially explain the operation and some of the causes of the short blast of Warwick Furnace at Pottstown, Pennsylvania, as described in the paper read at the Lake Superior Meeting, in August, 1880.*

The many inquiries concerning the details of furnace operation which followed the publication of the paper, and the expressed desire of furnace managers to be informed as to future operations of this plant, have encouraged the preparation of the following data. To make the record continuous, and add to the value of both contributions, the present paper commences where the review of a short blast of Warwick Furnace ended, and includes the data of another short blast of two months, and a subsequent continuous campaign of nearly five years, which, by comparison, we shall designate as "*the long blast.*"

Frequent visits to the plant in the five years, during which its operation could be studied, and correspondence with the manager, Mr. Edgar S. Cook, have given a knowledge as to general features and details, and the courtesy of the officers of the Company which has given free access to the books of record permits the presentation of data which it is believed will be welcomed by furnace managers. Interest will undoubtedly be increased by the remarkable results which Mr. Cook has achieved chiefly with anthracite coal in a furnace whose details of construction will scarcely be generally admitted as embodying advanced ideas, its height being but 55 feet, with a bosh diameter of 15 feet 6 inches, its bosh-slope comparatively flat, its crucible smaller than the average, and the heat of the blast never reaching 1000° Fahrenheit.

At present writing the credit of the best anthracite blast-furnace practice recorded in our *Transactions* is conceded to be that pursued by Mr. Fackenthal, at the Durham furnace, and Mr. Cook, at War-

* "A Short Blast at the Warwick Furnace," by John Birkinbine. *Transactions*, vol. ix., pages 51-59.

wick furnace. Fortunately each gentleman seems desirous of giving the credit to the other, and it is not the purpose of this contribution to decide this matter, but a perusal of the results herein given with those presented in Mr. Fackenthal's paper on "The Durham Blast Furnace, Pennsylvania," read at the Chattanooga Meeting, May, 1885,* will demonstrate that both gentlemen have by hard work and persistent application earned for themselves enviable renown as blast-furnace managers.

Although this paper is intended as a sequel to that read in August, 1880, it is deemed advantageous to present a résumé of the paper upon "A Short Blast at Warwick Furnace," read by the writer at the Lake Superior Meeting.

## Historical.

The furnace was blown in April, 1876. Prior to 1878 no extraordinary product was made from it, the best week's work being 189.5 gross tons. The stack was then 16 feet bosh and 55 feet high, constructed of brick banded with iron. Blast is supplied by a vertical non-condensing engine, with air-cylinder 96 inches diameter; steam-cylinder 48 inches diameter and 7-foot stroke, and heated in two iron-pipe hot ovens, one with 24, the other with 20 ∩ pipes; the aggregate heating surface being 2508 square feet. Steam is generated in six cylindrical boilers, 48 inches in diameter and 70 feet long, and one tubular boiler. The furnace was blown with six tuyeres.

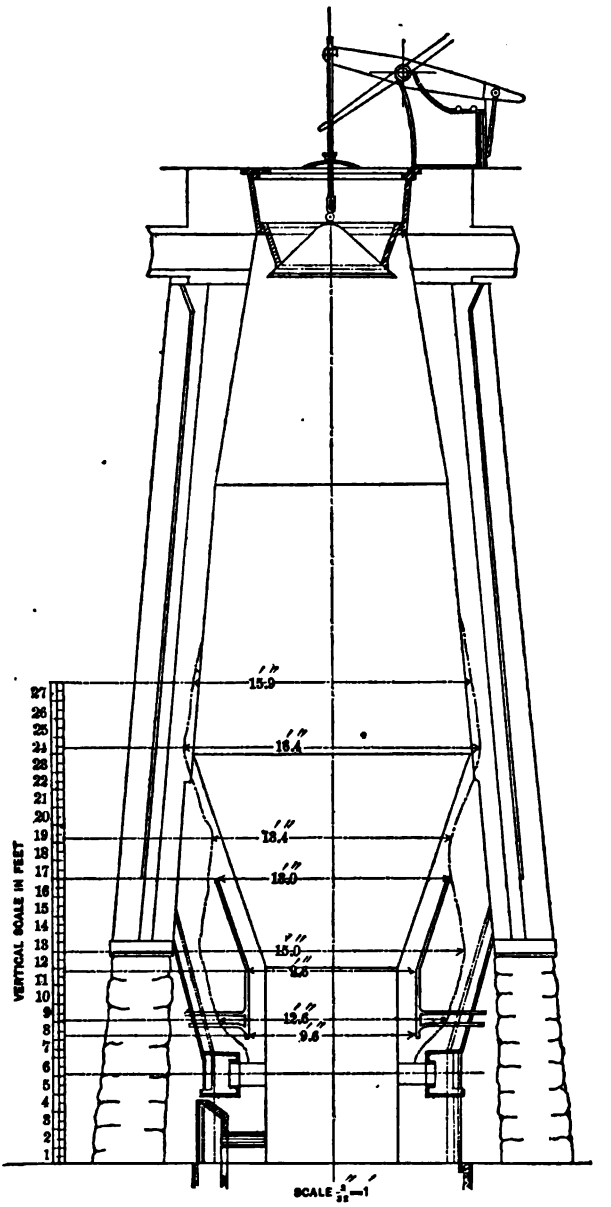
Fig. 1 shows the lines of the furnace as blown in December 15, 1880, and also (by broken lines) the size and shape in July, 1883. This figure is repeated from vol. xiii., p. 497, of our *Transactions*, where the method of determining the latter lines is explained.

The first blast under Mr. Cook's management continued for 105 weeks, during which time 37,400 tons (of 2268 pounds each) of pig-iron were made, an average of 356.2 tons per week. The consumption of coal for the blast (anthracite only being used) averaged 1.2875 gross tons (2884 pounds) per ton of iron—including the filling of the furnace. The ores used averaged 45.9 per cent., and 0.6875 gross tons of limestone were required per ton of pig-iron. During this blast the monthly maxima and minima were:

| | Maxima. | Minima. |
|---|---|---|
| Gross tons of pig-iron made, . . . . . | 1728.5 | 1143.5 |
| Gross tons of anthracite per ton of iron, . . | 1.375 | 1.2125 |
| Yield of ore in furnace, per cent., . . . . | 47.4 | 42.5 |

* *Transactions*, vol. xiv., page 130.

FIG. 1.



The record of this blast exhibits a remarkable uniformity in all the operations up to the last, when the furnace was forced to blow out, as the lining had so worn away as to permit part of the backing to fall in.

The work of the plant had been so satisfactory that the stack was relined to the same shape as before.

## The First Short Blast.

The next campaign was the short blast, described in vol. ix., from March 27th, 1880, to June 4th, 1880, less than 10 weeks, when the furnace made 3777½ gross tons of pig-iron. A tabulated record of the detailed operation for each week, with analyses of ores used and cinder made, was presented, and to describe the operation of the furnace and its behavior at the close of the blast, extracts from the furnace note-book were given verbatim.

These extracts from the diary of Mr. Cook show that the operation of the furnace during the last six days of the blast was entirely satisfactory, and, with the exception of six hours of slightly varying pressure and settling, there was no possible notice of irregularity of operation, the blast having practically ended less than two hours after the first serious indication of trouble, and within 18 hours from the time that the slightest intimation was given of any irregularity of working, which passed away 12 hours before the serious trouble commenced. When the stock in the well of the crucible was partly removed, an arch was found to have formed across the furnace at the top of the tuyeres which had supported the stock. This arch was composed of dry stock, coal, and limestone in small pieces, and a heavy black powder, evidently reduced ore, was packed very tightly, but yielded to a pick, and extended to a height of over 6 feet above the tuyeres.

No melted or fused material was found anywhere in this bridge, nor was there any chilled iron and slag below the tuyeres. At the level of and around the tuyeres, iron was found. When cleaned out, the inwalls were found to be in good condition, with no indications of cutting or irregular action. The boshes were destroyed for 10 feet above the tuyeres, and for the remaining distance partly fused and cindered. There was no scaffolded material found, nor was there any evidence of any accumulation having existed.

The speciality of Warwick furnace is a high grade of mill-iron; and, by referring to account given in August, 1880, it will be

noticed that the product for the short blast was 13.3 per cent. of No. 1 foundry iron, 13.8 per cent. No. 2 foundry, 69.8 per cent. No. 2 and No. 3 mill, and 3.1 per cent. mottled iron. One of the many criticisms in regard to that blast was that the furnace was cut out of shape by running on mill-iron and driving too fast; and the manager, although satisfied as to the incorrectness of this view, determined to test it in the blast commencing in August, 1880, particularly as the demand for foundry-iron at that time was urgent and the prices good. The developments have proved the incorrectness (as far as Warwick Furnace was concerned) of the views expressed by Mr. J. P. Witherow, in his published discussion of the paper referred to, entitled "Removing Scaffolds in Blast Furnaces." *

## The Second Short Blast.

The furnace was blown in August 27th, 1880, and started off satisfactorily, the product for the first eight days being 384 gross tons, all foundry-iron. The product for the first four weeks was exclusively foundry-iron Nos. 1 and 2, the average weekly yield being 391 gross tons. The fuel-consumption was all anthracite, averaging 1.32 tons (2968 lbs.) per ton of iron; and the ores averaged 45.4 per cent. of metal. Excluding "blowing-in" week, the fuel-consumption was 1.25 tons (2800 lbs.) per ton of iron.

At the beginning of the sixth week, irregularities began to show themselves, somewhat similar to those attending the close of the former short blast. Previous to October 3d, 1880, everything worked regularly and entirely satisfactorily. The analysis of the cinder of September 30th, 1880, was as follows, showing a good normal condition:

| | |
|---|---|
| Silica, | 36.75 |
| Alumina, | 16.75 |
| Lime, | 40.5 |
| Magnesia, | 5.2 |

The following extracts from Mr. Cook's diary are presented for comparison with similar data in the first paper:

"*Saturday, October 2d*, 1880.—Burden 3400 lbs. of ore, 2000 lbs. of anthracite coal; revolutions, 12; pressure, 8 to 9 pounds; blast, 875 to 950 degrees; cinder, gray, hot, and fluid, well fluxed; gas, abundant, gray, hot, and good; tuyeres, bright and clean; pressure

* *Transactions*, vol. ix., pages 60-71.

regular; stock settles regularly and level; made 53 tons of No. 2 iron; filled 80 charges.

"*Sunday, October 3d.*—Burden and revolutions the same as above; pressure, 9 to 11 pounds; blast, 900 degrees; at the second flush of cinder before the 8 A.M. cast, the stock made a slight jump; pressure increased from 9 to 10 pounds; at casting, the stock was uneven on top, being lowest towards the hot ovens and highest next to the boilers. On starting after cast: revolutions, 11½; the pressure was 11 pounds, which gradually fell to 10 pounds, and then to 9 pounds. At first flush after casting, the stock settled regularly, but was still uneven. At the second flush it made a slight jump just as cinder was tapped, and continued to settle after the jump fully two feet on the high side; cinder well fluxed, hot, fluid, and of a fair, gray character; gas abundant, clean, and hot. Revolutions, 12; pressure 9 pounds; blast 900 degrees. After third flush, the pressure increased to 11 pounds at 11½ revolutions, and then gradually fell to 10 pounds and continued regular until 2 P.M.; stock settled regularly and became level, making no jumps.

"At the 2 P.M. cast the stock settled two or three feet, becoming low on the side that was previously high. After the cast (revolutions 11; pressure 9 to 11 pounds), stock settled slowly; gas abundant, clean, and hot; melting slowly; cinder gray, hot, and fluid; tuyeres clean; no indications of hollow tuyeres.

"6.30 P.M.—Stock commenced to settle rapidly (no jumps), and continued to do so; revolutions 10 and 11; pressure 13 pounds. Previous to 6.30 the revolutions were 12; pressure 9 pounds; cinder gray and hot. The first flush after the pressure increased was one-half iron, the furnace had thrown no iron for weeks previously. Tapped at iron-notch, getting 13 tons of No. 3 iron in 4½ hours. The 2 o'clock cast was 16 tons of No. 2 iron in 8 hours. On starting again, revolutions 10; pressure 14 pounds; blast 800 degrees; there was very little gas, but it gradually increased in quantity and became abundant; tuyeres bright and clean; stock continued to settle regularly; pressure variable, running from 8 revolutions, 14 pounds, to 12 revolutions, 14 pounds; melted slowly. First flush was dry, thick heavy material which would scarcely run; stock continued to settle, but remained practically level. After flush, revolutions 9; pressure 14 pounds; gas was scant, but gradually increased. Tapped cinder again in two hours and then only got a trifle of thick, dry slag. After the second flush, opened the fore-part and *heaved out* a mass of fine, mucky material which set

fire to the cast-house roof and caused the engine to be stopped; on starting after one hour stoppage, revolutions 8; pressure 14 pounds; there was no gas; tuyeres were getting in bad condition; but the stock settled regularly and level. In about two hours flushed mostly iron and then cast, getting 10½ tons of mottled iron, which ran hot.

"*Monday, October* 4.—On stopping after cast, the tuyeres all closed with cinder and iron; the furnace stood two hours, in which time four tuyeres were opened. On starting, the engine scarcely turned centers, the pressure being very high; no gas; tuyeres worked badly; no signs of melting; opened fore-part and shovelled out stock; worked out a considerable mass of fine stuff. Started engine about 2 P.M.; pressure high and variable; very little gas; blew for two hours; cinder showing at tuyeres. Tapped at iron-notch, and got one bed of hot iron, the balance running slow and cold, chilling in trough and piling up at the iron-notch. We then opened the cinder-notch and got a large flush of hot, fluid cinder and cleared all the tuyeres. After this the tuyeres got better; pressure 4 pounds; revolutions 11; continued to melt freely.

"*Monday*, 9 P.M.—Tapped at iron-notch, getting 9 tons of No. 3 iron and plenty of cinder. The iron ran hot and freely and the furnace continued to work normally for the balance of the night; stock settling regularly and level. For the balance of the week the furnace worked perfectly uniform."

The week following, the seventh of the blast, the furnace made 407½ gross tons, and the eighth week 419½ gross tons of iron. The latter part of the ninth week, irregularities commenced again, although for the first four days the yield was good and the work perfectly regular. Referring to the manager's diary again, we quote as follows:

"*October 27th*, 1880.—Burden 3500 pounds of ore to 2000 pounds of coal (all anthracite); revolutions 12; pressure 8 to 8½ pounds; blast 800 degrees; cinder very gray, hot and fluid; stock settles perfectly regular and level; gas gray, large volume, but of poor heating-power; tuyeres bright and clean.

"*October 27th*, P.M.—Cinder gray, runs hot but not so fluid; gas gray, smoky and large volume; tuyeres clean and good; stock settles evenly and regularly; pressure high, after cast falling, and then remaining uniform between the flushes; filled 81 charges, and made 33½ tons of No. 1 and No. 2 iron.

"*October 28th*, A.M.—Burden 3600 pounds; after cast the pressure, which was 10 pounds, fell to 8 pounds and run from 8 to 8½ pounds

all day with 11 revolutions of the engine; cinder gray and hot; gas very gray and plentiful, but of poor heating-power. After 8 A.M. cast, the stock made a jump of two feet, being lowest on the east side, but became level before the 2 P.M. cast. Filled 38 charges in 12 hours.

"*October 28th*, P.M.—Shortly after 6 P.M. the stock commenced to settle faster on the hot-blast side of the furnace than on the boiler side, the stock being uneven; but the difference was not very great. After the 8 P.M. cast the difference increased, the stock settled regularly and the pressure was uniform; revolutions 11; pressure 8 to 8½ pounds; blast 800 degrees; gas clean, burned well and was of large volume; cinder gray, hot, and carries considerable dirt.

"*October 29th*, 2 A.M.—Cast, stock settled mostly at flushes. Made a jump at first flush of two charges; stock then became uneven, being lowest on the hot-blast or west side; settled on high side, but not so rapidly; with the irregular settling the pressure became changeable, varying constantly from 6½ to 10 pounds, being always highest after flushing; gas gray, hot and good; blast 850 to 900 degrees; tuyeres in good condition; continued to melt freely, making a gray, hot cinder; stopped filling.

*Analysis of Cinder, October 28th*, 1880.

| | |
|---|---|
| Silica, | 35 |
| Alumina, | 16.25 |
| Lime, | 41.22 |
| Magnesia, | 5.4 |

"*October 29th*.—As stock continued to settle, a large volume of flue-dirt or fine black dust was thrown over with the gas; the tops of the draught-stacks being black with clouds of dust, large quantities of which lodged under the boilers and in the hot ovens. Revolutions 11; pressure varying constantly from 6 to 10 pounds; tuyeres were fairly good, but were afterwards blackened with hard lumps; cinder was made freely, being good gray, but very dirty, the cinder getting sharper after the tuyeres darkened. Did not fill until the stock was down 21 feet. It was then level; the black smoke at the stacks had disappeared, but instead the gas assumed a greenish hue, tinged with pink; the bell became very hot; then filled 30½ net tons of anthracite coal and 30 tons of furnace-slag, filling gradually and only sufficiently to keep the bell cool; gas plentiful, very dusty; cinder clears tuyeres well. During the afternoon the metallic vapors at the stacks disappeared; the gas grew less dirty, burning

clean and naturally; the pressure became regular; revolutions 11; pressure 6 pounds; blast 900 degrees. Commenced filling with ore; mixture 2000 pounds of coal to 2500 pounds of ore.

"*October 29th*, 10 P.M.—Pressure increased to 14 pounds; revolutions 10; less gas; foamy cinder at tuyeres; flushed cinder, which ran hot, but very foamy and dirty, sharper than afternoon cinder; more ore-dirt coming into hearth; pressure kept high for two hours and then fell suddenly to 6 pounds; there was a large volume of very dirty gas with immense quantities of flue-dirt flying; pressure kept low, but changeable; tuyeres fair. At midnight cast 12 tons of gray mottled iron which ran hot; cinder hot and good. After this cast the pressure was 10 pounds; revolutions 10; very fine coal and dirt at all the tuyeres; cinder stiff and foamy, running very slowly; the furnace kept making gas.

"*October 30th*.—In trying to flush, got little or no cinder. Tapped at iron-notch, and the result was a little stiff unnatural cinder, which soon 'gobbed' up the hole. Stopped and opened fore-part; some of the tuyeres closed up at the nose with fine ore and coal-dirt and stiff cinder; even with tuyeres clear, we could get no pressure at the iron-notch with 10 pounds pressure at the engine; the hearth was apparently full of dirt. After opening the fore-part, and cleaning a large hole, the engine was started. A few pieces of large coal were blown out, followed shortly afterward by an immense quantity of red-hot, perfectly dry dirt, resembling a black, sharp sand, with some coal-dust, which ran like red-hot pewter sand, throwing out coal-sparks and others resembling iron; it could not be removed from the fore-part fast enough, piling up higher than the tymp. Had to stop, and clear it away, and then commenced again with the same result. This time the material was a little coarser in grain than at first, the coal being the size of 'pea' or 'chestnut.' Continued to blow out and clean up until noon, when the pressure was so low that we could not get any more material out of the hearth.

"During the last blow, quite coarse stock was obtained along with the dirt; and thinking, therefore, that the greater part of the material was out, we closed up the fore-part, and commenced to run regularly. Pressure low and steady; revolutions 12; gas plentiful and hot, but very dirty; pressure 5 pounds. The bell was very hot, and we had to fill it; gas wild on top; slackened engine to 8 revolutions while filling; tuyeres dull; foamy thick slag showing at them; melting slowly. In two hours from the start, flushed cinder, which ran sluggish and dirty, and would not clear

tuyeres. In another hour, filled four cars with very hot, fluid, black slag carrying a great deal of dirt; hearth full of dirt; cinder would not clear tuyeres; stopped to clean pipes, but after this the furnace refused to melt; only thick, foamy cinder showing at tuyeres. Tapped again, but got nothing. Opened fore-part and blew out quite a pile of dirt, and then the coarse stock followed; on stopping to close the fore-part, several pipes filled with cinder. Started up again with poor gas; high pressure, no melting.

"*October 30th*, P.M.—After blowing two hours, tried to flush, and drove 1½ inch bars under tymp 4 or 5 feet, getting nothing but a thick, heavy, half-fused slag, similar to that hanging around the tuyeres; tuyeres gradually refused to take blast; pressure 10 pounds; engine scarcely turning, and then only by opening escape-valve on receiver.

"*October 31st*, 6 A.M.—Stopped engine, and commenced to take down pipes; a hole being cut above No. 6 tuyere, quantities of dirt rolled out similar to that blown from at the fore-part on Saturday."

Mr. Cook's analysis of the stiff cinder showing at tuyeres, and closing them at the nose, on October 30th, is as follows:

| | |
|---|---|
| Silica, | 16.75 |
| Alumina, | 7.00 |
| Protoxide of iron, | 50.9 |
| Lime, | 14.9 |
| Magnesia, | 3.9 |

It was as black and dense as finery- or mill-cinder.

The analysis of the dirt taken from the top of No. 6 tuyere is here given:

| | |
|---|---|
| Coal, | 47.6 |
| Magnetic ore, | 46.0 |
| Limestone, | 6.4 |

(Booth, Garret, and Blair.)

The analysis of this magnetic ore was:

| | |
|---|---|
| Silica, | 17.4 |
| Alumina, | 3.64 |
| Iron, | 54.37 |
| Lime, | 9.02 |
| Magnesia, | 2.37 |

resembling very closely the composition of Boyertown ore used at the furnace; this sample was taken from above No. 6 tuyere, after

the stoppage, being similar to that blown out through the fore-part; as it run from the top of the tuyere arch, it was red hot.

The total product of iron for the blast was 3430½ tons; 29.2 per cent. being No. 1, and 40.1 per cent. No. 2 foundry-iron, 21.9 No. 2 mill and 8.1 per cent. No. 3 mill-iron and 0.7 per cent. of mottled iron.

After the first short blast, the only repairs made were to put in a new bosh, 15 feet 6 inches in diameter, and to extend it 2 feet higher, making the top of the bosh 23 feet from the bottom instead of 21 feet, as before. The inwall showed no wear, and was not touched. When the furnace was cleaned out after the second short blast, the bosh was found to be essentially in the same shape as at the conclusion of the previous blast, as shown by the plate (*Transactions*, vol. ix., page 58), with the exception that a larger amount of brick had been cut out, the diameters at corresponding sections being from 3 inches to 6 inches greater than before. The additional 2 feet, added to the bosh, showed no appreciable wear, the melting action not extending that high; the inwall was in perfect condition, not having worn to any noticeable extent; the bosh walls were as smooth and regular as when the bricklayers left them, only being of different shape. There were no gutters or other evidences of the cutting action of the blast working in channels, characteristic of a scaffolded furnace. It was a clear case of fusion by fervent heat, and plainly showed the fallacy of the former criticisms that running on mill-iron had been the cause of the previous short blast, demonstrating as it did, that the increased temperature, accompanying the foundry-iron made, had melted out the brickwork of the bosh to a greater extent, and in less time. As in the other instance, no evidence of scaffolding or of scaffold-material in the ordinary sense could be found.

Directly under the tuyeres was a layer of partially-fused cinder and iron, several inches thick, extending over the area of the crucible; below this, the material was fine, heavy dirt, and, for 6 or 7 feet above the tuyeres, the same material was found, but there were no large lumps of coal. The analysis of this fine ore-dirt, or sand, was similar to the analysis given on page 10. Above this fine ore-dirt, or sand, was the stock, which was in first-class condition. The inwalls had not worn away any, the dimensions being essentially as built.

As these two similar experiences were new developments in iron-making, information was sought from all quarters, but nothing of a

similar nature could be found; the mystery still continued, and, although more or less discouraged, the company decided to make another trial.

The manager supposed that the trouble arose from the melting away and undue enlargement of the bosh, while the upper part of the furnace remained the same size as it was built, the disproportion existing between the parts of the furnace being, in some unaccountable way, responsible for the sudden termination of the blast. He was positive in his own mind that there was no melted scaffold and that the difficulty was entirely of a different nature; it remained for the next blast to prove the correctness of his theory, and give opportunities to further study the cause of the trouble. In making the repairs, the bosh was merely patched up with 9-inch brick, and an effort was made to hold the bosh to certain fixed dimensions by means of a series of one-inch iron-pipe coils running vertically, and arranged in sections all around the furnace, substantially as shown by the sketch, Fig. 1.

## The Long Blast.

The furnace was blown in again, December 15th, 1880. It started off very satisfactorily, making, in the first nine days, 447½ gross tons of No. 1 and No. 2 foundry-iron. It continued to work regularly and well for seven weeks, the average weekly yield for that time being 408¾ gross tons of iron. The fuel-consumption, all anthracite, was 1.35 gross tons (3024 pounds) including "blowing in," the yield of the mixture of ores being 42.7 per cent., and the largest weekly product was 433½ gross tons. As in the previous campaign, the existence of peculiar conditions began to show themselves about the same period of the blast, now known to be peculiar from previous and similar experiences, but did not cause trouble or any particular anxiety on the part of the manager, who was constantly on the alert for developments until the eleventh week, commencing February 27th, 1881.

On the Saturday previous, "*February 26th*, the iron broke out through the jacket, at the bottom of the furnace, just as the cast was being run. It ceased to run at the iron-notch, but large streams of cinder and iron came out from this hole. The furnace was stopped nearly two hours, and, on starting, the pressure became irregular, and the stock settled by jumps. After the second flush, the iron broke out again at the same place, causing another stop-

page of three and a half hours. The stock settled regularly and level.

"*February 26th*, P.M.—Pressure regular, and all the conditions appeared normal; cinder good and gray, hot and fluid."

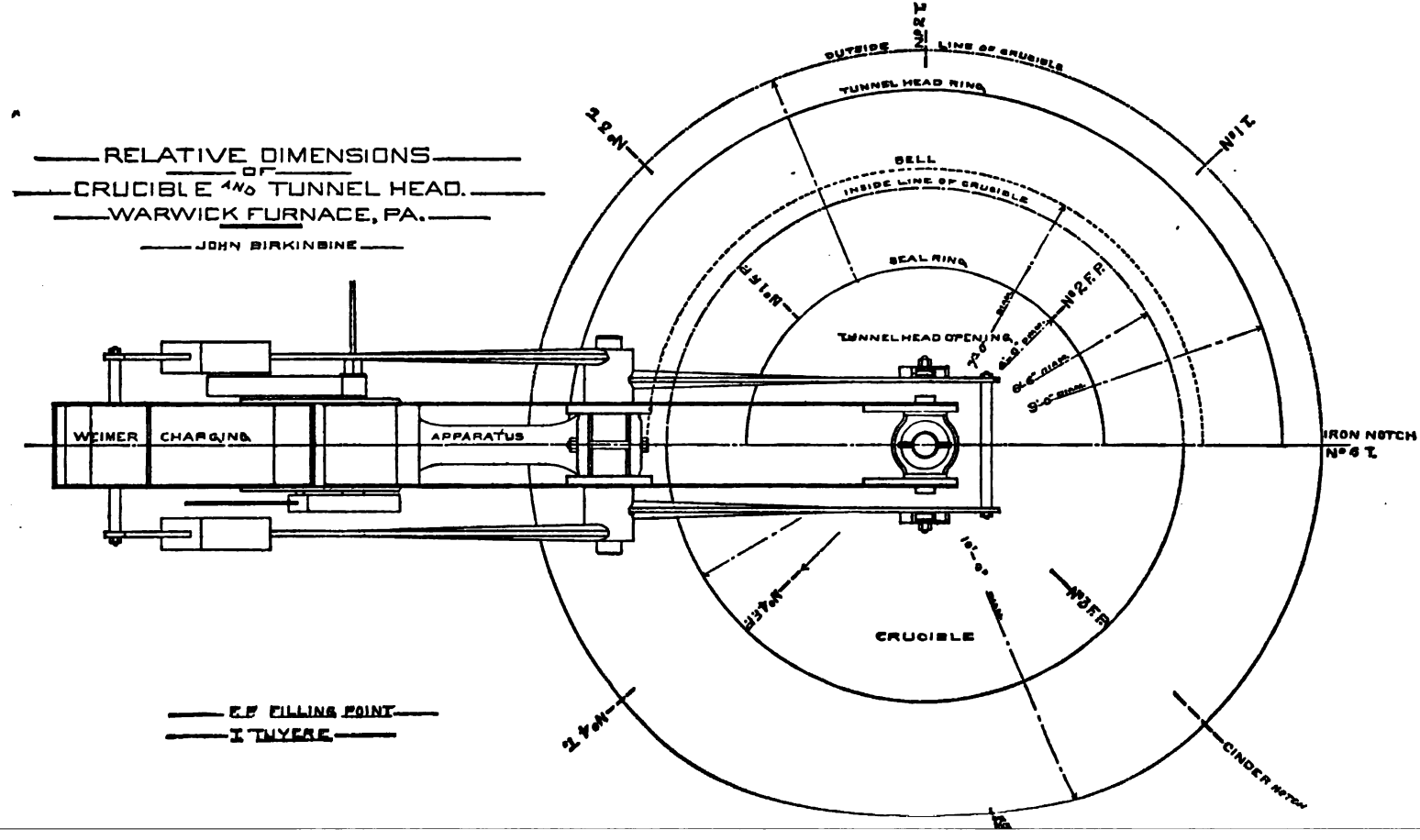
*Sunday, 27th.*—The manager's notes state, "no trouble anywhere; worked regularly; made 58 tons of No. 2 foundry-iron; charges 84; burden 3500 pounds of ore to 2000 pounds of anthracite coal."

During the week, the manager, from his notes, appears apprehensive of a return of the former "dirt troubles." All the indications were carefully noted, seemingly only trifling; yet from previous experiences he felt confident of another "campaign." One incident was the dirty condition of the slag, which, though it flowed hot and liquid, carried quantities of fine dirt; as the cinder was run into the cars from the spouts, the dirt would separate from the slag, being thrown out at a different angle, and could be collected on a shovel. On examination, it proved to be the identical ore-sand that had caused the previous short blasts. On examining the slag-runner, particles of metallic iron could at times be found; to ascertain if this came from the furnace in a metallic state, several deep holes were made in the upper part of the runner, nearly on a level, to collect any iron that might be carried over by the slag. No metal could be found in these holes, but still the globules of iron would be noticed in the lower part of the runner. The manager soon became satisfied that it was produced from the material designated as ore-dirt or sand, and after-experiments proved this quite conclusively. This sand was washed out of the furnace; and in flowing down the long runner carried by the molten slag it was fused and converted into metallic iron. It was chiefly found in the lower end of the runner.

Another important indication was the variation of the pressure-gauge close to the furnace. Every considerable variation, particularly before and after flushing, was noted by the keeper on cards prepared for the purpose. The gas also received special attention; in fact the furnace was as carefully watched in every particular as a sick patient would be at the hands of a trained nurse and efficient physician. The results, after months of waiting, rewarded these endeavors, and the manager's apprehensions proved to be well-founded.

Fig. 2 shows the relative location of the tuyeres, and the iron- and cinder-notches in the hearth, and of the filling-places,

FIG. 2.


RELATIVE DIMENSIONS
OF
CRUCIBLE AND TUNNEL HEAD.
WARWICK FURNACE, PA.
JOHN BIRKINBINE
OUTSIDE LINE OF CRUCIBLE
TUNNEL HEAD RING
BELL
INSIDE LINE OF CRUCIBLE
SEAL RING
TUNNEL HEAD OPENING
No 1 F.P.
No 2 F.P.
No 3 F.P.
No 4 F.P.
No 1 T.
No 2 T.
No 3 T.
No 4 T.
No 5 T.
No 6 T.
IRON NOTCH
CINDER NOTCH
WEIMER CHARGING APPARATUS
CRUCIBLE
F.P. FILLING POINT
T TUYERE

charger, etc., at the tunnel-head; one-half of the top rings being removed, to show the relative dimensions of crucible, bell, charging-opening, etc. The top fixture is a Weimer charging-apparatus, operating by one beam the bell, 7 feet in diameter, and by another beam the seal covering the charging-opening, 4 feet 6 inches in diameter.

The tuyeres and filling-places are numbered according to the furnace-practice.

A brief account of the next six to nine months' work will be given.

From Sunday, February 27th, 1881, to Saturday, March 5th, 1881, no further disturbance was noted; the furnace worked along regularly and with good results.

Quoting again from the diary:

"*Saturday night, March 5th*, 1881.—Irregularities began to show themselves, continuing for several days. The cinder was fair gray, hot and fluid, analysis showing silica 35.25 per cent.; stock settled chiefly by jumps; large amounts of black, heavy flue-dirt were carried over by the gases; gas abundant and hot, but very dirty; tuyeres worked clean; pressure irregular, being always highest, however, before the flush than after it." (It may be well to remark here, what was afterwards learned to be an almost invariable rule, that, whenever the pressure after flushing was repeatedly and continuously higher than before, it was a reasonably sure indication, not of the presence of ore-sand filling the cavities of the brick-work, but that it was in motion and moving down to the tuyeres. Ordinarily speaking, when the slag is allowed to nearly reach the tuyeres, the pressure will be higher before than after the discharge of slag. The reverse invariably indicated a cause disturbing the uniformity of the operations of the furnace.)

"*Sunday, March 6th*, 1881.—Cinder fair, gray, hot and fluid; stock continued to settle mostly at flushes; soon Nos. 5, 4 and 3 tuyeres began to work dirty; the next two flushes were cold, black, heavy cinder. After this the stock settled regularly and became level; previously it had been high at No. 4 filling place and lowest at No. 2, the difference at one time being fully six feet; the cast was Nos. 3 and 4 mill-iron. After cast stock settled regularly; gas clean and hot; pressure regular; cinder fair and gray; the cast following being 14 tons of No. 2 foundry-iron" (6 hour casts).

From Sunday night the furnace worked fairly and regularly, making 57 and 58 tons of No. 2 and No. 3 iron per day, until—

*Tuesday night, March 8th*, 1881, when "the stock became uneven,

being low between No. 1 and 2 filling places, and high at No. 4. Stock settled only by jumping at flushes; pressure very irregular, sometimes falling between the flushes, with rushes of dirt and a red, smoky, very hot gas." As a rule the gas was plentiful and hot with the high pressures, although sometimes it would be short; the tuyeres kept open and bright. A hole was drilled through the brickwork about 8 feet above No. 4 tuyere, and the masonry was found to be 30 inches thick, instead of about 42 inches, as when first laid; no brick was left in front of the coils, it having been all melted away. Next to the coils was two or three feet of ore-sand similar to analysis given on page 842. It was not burned or melted in mass, but was comparatively loose, except a thin layer next to the active part of the furnace. A bar could be easily pushed in through it and would not get hot. A one-inch pipe was put in this hole and air was blown through it. To quote again:

"*Wednesday.*—After the 2 A.M. cast the stock did not settle until the flush; it then made a jump and afterwards continued to settle rapidly during the balance of the night; pressure uniform, being about 6 pounds; revolutions 12; blast 900 degrees; tuyeres worked hot, but a good deal of soft dirt came before them and melted; gas good; cinder gray and very hot.

"At the 2 P.M. cast, tested the opening above No. 4 tuyere, found dirt all gone and the bar was hot just inside of the brick-work; stock perfectly level on top; the one-inch pipe was then taken out."

For the balance of the week the furnace worked with perfect regularity, making a fair yield of iron, 55 to 60 tons per day, mostly of foundry grades. The average analysis of slag was

| | |
|---|---|
| Silica, | 37.75 |
| Alumina and iron, | 18. |
| Lime, | 35.6 |
| Magnesia, | 8.5 |

The following notes on the work of the week ending March 19th, 1881, are of interest.

"*Monday, March 14th.*—The stock commenced to settle by jumps at flushes, it had previously worked regularly in all respects for four or five days; it continued to settle at flushes all night, and early in the evening the stock got uneven on the top, being lower at No. 2 filling point and high at No. 4; the lowest point seemed to be directly above the iron notch. Pressure irregular; gas also irregular in volume, although mostly of very good quality; aimed to keep up

12 revolutions and run the blast as hot as possible, being about 900 degrees. The high heat of the blast seems to give the best results when the stock is sticking and jumping.

"*Tuesday, March 15th.*—The stock settled regularly and evenly. During the week holes were drilled about 8 feet above Nos. 1, 2 and 3 tuyeres; the bosh was found in fairly good shape at that level above Nos. 1 and 2 tuyeres; and no dirt or ore sand appeared at No. 1 tuyere. The brick was clean, and stock coarse. Considerable sand was found at No. 3 tuyere, and also above No. 4 tuyere. At No. 4 a hole was drilled directly above the tuyere-arch at the foot of the pipe-coil, where there was found a fair thickness of brick and at least one foot of ore-sand. At No. 1 tuyere a similar hole was drilled, but no dirt was found. As the stock usually settled out of level either at casting-time or between the cast and the first flush of cinder, it would seem that the front part of the furnace over the iron- and cinder-notches cleaned itself continuously, and that it was from this section that the cinder obtained its dirt, while in the rear of the furnace the dirt could not get away so readily and lodged over the tuyeres, accumulating until it was brought down in quantity; in consequence, the front of the furnace worked freer and cleaner, and naturally settled the most rapidly, while the furnace was standing; and between the casts and flushes, when the blast is on continuously for two or three hours, the rear of the furnace being dirty along the walls and possibly soft or pasty, the stock had not the same freedom of movement, and was inclined to move slowly along the walls, often sticking to them, moving the most when the upward pressure was removed by the slackening of the blast at the flushes.

"Thinking this view plausible, on March 17th, Nos. 3 and 4 tuyeres were pulled back 4 inches, making 7 inches in all; they having been withdrawn 3 inches previously. This was done with a view of directing more blast along the walls, to prevent ore-sand accumulating in such large quantities. It was found to work satisfactorily, and later on the nozzles were dispensed with; the belly-pipe being clayed into the butt and air blown through the nose of the 5-inch tuyeres, although the belly-pipes were 4½ inches in diameter."

For the balance of the month of March (from the 21st), the furnace worked fairly well, giving good results, averaging about 60 gross tons of iron per day.

Under date of March 22d, the notes state that "Holes drilled

over No. 6 and No. 2 tuyeres show little or no dirt and about 30 inches of brick. The dirt appears to run mostly from No. 5 to No. 3 tuyere."

The "dirt-troubles," as they are now termed, continued through April, 1881, with more or less frequency, sometimes being very bad, although the yield of the furnace was kept up to from 350 to 425 gross tons per week, and no remedy which could be applied seemed to prevent their occurrence. At the suggestion of several furnace managers the experiment of a 5-feet diameter bell in place of one of 7-feet diameter was tried; and on April 25th the furnace was stopped and the change made.* It proved to be of no benefit whatever, but rather the reverse: it did not remove the cause of the "dirt-troubles," neither did it make them any worse. So far as they were directly concerned the conditions remained unchanged; but the economy and yield of the furnace was materially affected, as will be shown by data hereafter.†

The irregularities consequent upon the dirt-accumulations continued through the year 1881.

The total product for the year 1881 was 18,290 gross tons of iron; 93.28 per cent. of which was foundry and gray forge, 3.15 per cent. mottled, and 3.57 per cent. white iron; the ores yielded an average of 47 per cent. The fuel per ton of iron (all anthracite coal) was 1.46 gross tons (3270 pounds); and there was used an average of 0.9125 ton of limestone per ton of iron; the average revolutions of the engine 11.7 = 8233 cubic feet of air per minute (engine measurement without allowances); average pressure 6.7 pounds at furnace; the heat of blast averaged 896 degrees; stoppages, 439 minutes per week; tuyeres lost, 12.

*April 6th*, 1882.—The 5-foot bell was dropped into the furnace purposely and the 7-foot bell restored; the smaller bell was in use about one year, and the difference in results attained with the two sizes shows as follows:

| Diameter of Bell. | Average Burden. | Average Yield of Ore. | Iron per week Average gross ton. |
|---|---|---|---|
| 7 feet, | 3305 lbs. per 2000 lbs. coal, | 45.1 per cent., | 392.3 |
| 5 " | 2740 " " " | 47.9 " | 328.8 |

Returning to the use of 7-foot bell again, the yield of furnace increased and the fuel per ton of iron was reduced.

* *Transactions*, vol. xiii., pages 526 to 529—Discussion on Bells.

† Mr. Cook analyzed dirt taken from the walls of the furnace, April 3d, 1881, and found 77.49 per cent. of iron ore, and 22.51 per cent. of carbonaceous matter.

The "dirt-troubles" continued through 1882, but were less severe. The manager learned in a measure to foretell their coming and knew better how to apply remedies.

On *May 15th*, 1882, the coils around the bosh of the furnace commenced to leak, owing to breakage of elbows connecting them with the feed- and discharge-pipes, necessitating turning off the water and allowing the coils to burn out. These coils had been in use for nearly a year and a half, and had held the walls in fair shape up to this time. Their position is shown in the sketch of the furnace, Fig. 1. The brickwork showed the effect of the loss of water-cooling immediately; and it was a doubtful matter for a month or two whether it would be possible to keep the furnace in blast. All around the furnace from the mantle to the tuyeres, the brick became very hot; cracks opened, through which the blast and gas blew; and pressure averaged very low, running down to 2 or 3 pounds in the furnace with 11 or 12 revolutions of the engine. Finally the furnace closed up the cracks, making its repairs internally; the pressure increased to 4 and 5 pounds; and the manager felt quite relieved.

During 1882, one-fourth coke to three-fourths anthracite coal was used; this helped to reduce the intensity of the "dirt-troubles," and as the manager became used to them, learning to expect them, they ceased to cause anxiety.

The total product for 1882 was 19,762 gross tons of iron, 93.2 per cent. being foundry and gray forge, 4.1 per cent. mottled, and 2.7 per cent. white iron; the fuel consumption (one-quarter coke) was 1.4 tons (3136 pounds) and the limestone used was 0.92 ton per ton of iron; the air per minute was 8233 cubic feet; average pressure of blast, 4.6 pounds; blast temperature, 900 degrees; stoppages per week, 431 minutes; tuyeres lost, 7.

The year 1883 gave less trouble and anxiety than either of the preceding years. It seemed that the larger the furnace became worn above the bosh, the less difficulty was experienced in the crucible. The bottom of the furnace began to fill up this year; the furnace was blown in on a sandstone bottom; this cut away very rapidly, and the iron-trough was lowered fully 18 inches. During 1883, the trough was raised first 6 inches and then 6 inches more, making a total of 1 foot. It remained in this position until the end of the blast. There was but little trouble with the iron-notch after the bottom ceased to cut down.

The product for the year 1883 was 21,676 gross tons of iron, 94.76 per cent. being foundry and gray forge, 2.97 per cent. mottled, and

2.27 per cent. white iron. The average yield of ore was 50.2 per cent.; consumption of fuel (¾ anthracite, ¼ coke) 1.2875 gross tons (2884 pounds); and 0.875 ton of limestone was used per ton of iron; the air per minute (engine measurement) was 8374 cubic feet. Average temperature of blast, 869 degrees; average pressure, 5 pounds; stoppages, 494 minutes per week; tuyeres lost, 12.

The white iron made this year was of a peculiar nature, the fracture being somewhat similar to spiegel, very uneven, divided up into different planes or faces at varying angles. It had fair strength, and carried as much silicon as the gray forge quality, about $\frac{4}{10}$ of one per cent. In the puddling furnace, it acted very much like gray forge iron, requiring quite as much work and yielding a tough, fibrous bar. Its production was attributed to comparatively small slips of fine ore-dirt falling into a bath of gray metal. The carbon in the latter would reduce the ore to metallic iron, lowering the grade of the following cast. If the ore-dirt bore a small percentage to the amount of gray iron in the crucible, only a few beds would be of the peculiar white iron described, the remainder of the cast being gray forge or even No. 2 iron. If the percentage was larger, nearly the whole cast would be white iron with one or two beds of gray iron, the slag all the time indicating gray iron. If still larger, the slag would become raw and the whole cast would be white iron of the ordinary kind, losing the peculiar appearance of spiegel.

During December, 1883, an extra set of boilers was completed and connections were made for steam, gas and water. This helped the furnace very materially in 1884; previously it was not possible, for want of steam, to give the furnace all the air demanded by its increased size. The new set of cylinder boilers consisted of three upper boilers, 48 inches in diameter by 52 feet long, with necks connecting them to three lower boilers 36 inches in diameter and 52 feet long, and avoided the necessity of stopping the furnace for two weeks a year to clean out the scale.

During 1884 the output was 22,892 gross tons of iron, or an average of over 440 tons per week. There was not a week in the year that the product fell below 410 tons, except when obliged to make long stops to repair the hot-blast ovens, which became troublesome this year.

The ores yielded 50.2 per cent. The consumption of fuel (¼ coke) was 1.2875 gross tons (2884 pounds), and 0.7375 ton of limestone was used per ton of iron; the average consumption of air per minute (engine measurement), was 8972 cubic feet; average pres-

sure, 6.76 pounds; average temperature of blast, 851 degrees; stoppages, 322 minutes per week; tuyeres lost, 13.

The "dirt-troubles" still continued occasionally, but were of less intensity, and seldom gave rise to any serious difficulty.

The iron made was 95.4 per cent. foundry and gray forge, 2.2 per cent. mottled, and 2.4 per cent. white iron. The largest weekly product of the year was 516 gross tons. Mr. Cook expected to blow out for repairs in the spring of 1885; but, as the results obtained were so satisfactory, he decided to run until fall, taking his chances with the ovens, which were liable to give out at any time, or might last several months. The mains in one oven were exposed; and, although the arches had been patched several times, he could fix nothing permanently. In the other oven nearly all the pipes were in a bad condition. These ovens had been in constant use for nearly 10 years, with no costly repairs whatever, and of course could not be expected to last much longer without thorough overhauling, particularly as the furnace had in its earlier history passed through a series of troublesome experiences, causing short and unsatisfactory campaigns. They were constructed to heat about 5000 cubic feet of air per minute, having a total heating-surface of 2508 square feet. For the last seven years, from 8000 to 9000 cubic feet of air per minute had been driven through them, giving a back-pressure of from 3 to 4 pounds, which was a dead weight on the engine, and represented a considerable loss of steam-power.

The work for 1885, to the close of the blast, on September 1st, was as follows: Iron made, 18,715½ gross tons, an average of 514 tons per week; the ore averaged 54.9 per cent.; fuel consumed (one-fourth coke) 1.0875 gross tons (2436 pounds); 0.6375 ton of limestone was used per ton of iron; the air per minute averaged 9844 cubic feet; the pressure averaged 6 pounds; temperature of blast 813 degrees; stoppages 487 minutes per week.

The iron made was 95.1 per cent. foundry and gray forge, 2.5 per cent. mottled and 2.4 per cent. white iron. Tuyeres lost, 10.

The best monthly work averaged 570 gross tons per week, the ores averaging 59 per cent.; fuel consumption (one-fourth coke), 0.95 gross tons (2128 pounds), and 0.60 tons of limestone were used per ton of iron; the average blast temperature was 843 degrees; stoppages, 344 minutes per week.

The largest weekly yield of the blast was 615½ gross tons, with a consumption of 0.95 gross tons of fuel and a blast temperature of 841 degrees.

The total product of the blast was 101,335½ gross tons of iron in 245 weeks, or a general average of 413.6 gross tons per week.

With the advent of warm weather in July and August of 1885, great difficulty was experienced on account of the constantly recurring *break-outs* of cinder around the tuyeres and in the jambs between the tuyeres, and of gas coming from the top of tuyeres and at level of mantle. It became necessary to flood these portions of the brick-work with water in order to assist the air in cooling them.

The tuyeres began to sink at the nose and it became almost impossible to hold them up as there was scarcely any brick-work left to support them, the tuyere-houses being all more or less cracked.

With the return of the cold weather, the furnace would, probably, have filled up again and made her own repairs, but as Mr. Cook had arranged to reline the stack and had worked up all the stock by September 1st, he blew out.

The blowing down was successful. The bell and hopper having been left in position, everything was kept cool with the aid of Mr. W. J. Taylor's water-spray arrangement, and the stock was melted out to within a few feet of the tuyeres. In 12 hours after taking off the blast, the dam was removed and all the stock shovelled out to a considerable distance below the level of the tuyeres.

The available thickness of the brick in the bosh was found to be only 4½ inches, showing that the furnace had been running on from 4½ to 9 inches of masonry for over two years. There was no bosh-taper, except for a couple of feet at the top: below this the sloping wall was all melted away, and the shape was practically that of a straight-bosh furnace.

The inwall at and below the stock-line was in good condition and would have lasted for several years longer; above the bosh on one side it had disappeared altogether, although on the other side it showed considerable thickness. It was smooth, but worn oblong instead of round.

In one week's time the furnace was ready for the bricklayers to commence relining. By December 12th the furnace was in blast again, the company having made extensive repairs to the stack, built four sections (24 pipes each) of the Durham Cooper hot-blast stove, changing the gas-flues and the hot and cold blast-pipes to suit. Few alterations were made in the shape of the relined furnace, the inwall being exactly the same as before. The crucible was made 8 feet 9 inches in diameter instead of 6½ feet, the diameter of the bosh remaining 15½ feet as formerly, but the thickness of the bosh-walls

was 18 inches instead of 42 inches. Below the tuyeres the crucible wall was built 32 inches thick.

*Resumé of the Long Blast of the Warwick Furnace, Pennsylvania.*

| Year Ending. | Gross Tons of Iron Made. | Percentage of Foundry and Gray Forge Grades. | Average Yield of Ores. (Per Cent.) | Fuel Consumption per Ton of Iron. (Pounds.) | Character of Fuel. | Limestone per Ton of Iron. (Gross Tons.) | Average Air per Minute. (Cubic Feet.) | Average Temperature of Blast. (Degrees F.) | Weekly Stoppages. hrs. | Weekly Stoppages. min | Tuyeres Lost. | Average Pressure of Blast. (Pounds.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 15th, 1881. | 18,290 | 93.28 | 47. | 3,270 | Anthracite. | 0.912 | 8,233 | 896 | 7 | 19 | 12 | 6.7 |
| Dec. 15th, 1882. | 19,762 | 93.2 | 47.5 | 3,136 | ¾ Anthracite. ¼ Coke. | 0.920 | 8,233 | 900 | 7 | 11 | 7 | 4.6 |
| Dec. 15th, 1883. | 21,676 | 94.76 | 50.2 | 2,884 | ¾ Anthracite. ¼ Coke. | 0.875 | 8,374 | 869 | 8 | 14 | 12 | 5. |
| Dec. 15th, 1884. | 22,692 | 95.4 | 50.2 | 2,884 | ¾ Anthracite. ¼ Coke. | 0.737 | 8,972 | 851 | 5 | 22 | 13 | 6.76 |
| Sept. 1st, 1885.* | 18,715½ | 95.1 | 54.9 | 2,436 | ¾ Anthracite. ¼ Coke. | 0.637 | 9,844 | 813 | 8 | 07 | 10 | 6. |
| Totals and Averages. | 101,335½ | 94.4 | 50.5 | 2,920 | | 0.804 | 8,727 | 866 | 7 | 18 | 54 | 5.99 |

*Record of Best Weekly Work.*

| Years. | Size of Bell in Feet. | Gross Tons of Iron made. | Gross Tons of Fuel per Ton of Iron. | Average Yield of Ore. Per Cent. | Average Temperature of the Blast. Degrees. |
|---|---|---|---|---|---|
| 1881..... | 7 | 433½ | 1.25 | 44.5 | 806 |
| 1881..... | 5 | 407½ | 1.3 | 52.3 | 875 |
| 1882..... | 7 | 453½ | 1.25 | 51.5 | 800 |
| 1883..... | 7 | 480½ | 1.1 | 58.8 | 825 |
| 1884..... | 7 | 516 | 1.15 | 55.9 | 833 |
| 1885..... | 7 | 615½ | 0.95 | 58.3 | 840 |
| Av'ge of best 8 consecutive weeks, 1885. | 7 | 570 | 0.9825 | 58.4 | 843 |

*Eight and a half months; the furnace year was from December 15th of one year to the same date of the next year.

During the last thirty-five weeks of the blast there was weighed into the furnace:

| | | |
|---|---|---|
| 32,872 | gross tons | of ore, |
| 14,746 | " | of anthracite coal, |
| 4,915 | " | of coke, |
| 11,556 | " | of limestone, |
| a total of 64,089 | gross tons, | |

from which 18,080 gross tons of pig iron were made, showing a consumption of 3.545 tons of stock to produce one ton of pig iron; of which 1.087 tons were fuel and 2.458 tons were ore and flux.

The stock-line at full charge was ten feet in diameter, and up to this line (say 49 feet from the hearth) the working capacity of the furnace was about 5400 cubic feet. The average ore-mixtures were as follows:

*During* 1881.—Thirty to forty per cent. Boyertown magnetites, twenty to thirty per cent. hematites, ten to twenty per cent. Jersey magnetites, ten per cent. mill-cinder, ten per cent. Seisholtzville magnetite.

*During* 1882.—Thirty to fifty per cent. Boyertown magnetite, ten to twenty per cent. hematites, twenty to thirty per cent. Jersey magnetites, ten per cent. mill-cinder, ten per cent. Seisholtzville magnetites.

*During* 1883.—Fifteen to fifty per cent. Boyertown magnetite, ten per cent. hematites, twenty to forty per cent. Jersey magnetites, ten per cent. of mill-cinder, fifteen per cent. forge cinder, ten per cent. Seisholtzville or New York magnetites.

*During* 1884.—Fifteen to forty per cent. Boyertown magnetites, ten to fifteen per cent. hematites, twenty to thirty per cent. Jersey magnetites, ten per cent. mill cinder, ten per cent. "Blue billy,"* ten per cent. Seisholtzville magnetites. During the latter part of the year, twenty-five per cent. Elba ores were used with the smaller percentage of Boyertown ore.

*During* 1885.—Fifteen to thirty per cent. Boyertown (stopped mining), twenty to forty per cent. Elba, ten per cent. "Blue billy," ten per cent. Jersey magnetites, ten per cent. mill cinder, ten to fifteen per cent. Seisholtzville, five to ten per cent. hematites (occasionally).

To give an approximate idea of the general composition of the ore-charges, the following representative analyses are presented:

* Residuum from roasted pyrites used in manufacturing sulphuric acid.

| | Seisholtzville. | Boyertown Roasted. | Mill Cinder. | Jersey Magnetites. Fine. | Jersey Magnetites Coarse. |
|---|---|---|---|---|---|
| Silica | 12.9 | 12.5 | 24.9 | 12.37 | 14.75 |
| Alumina | 2.8 | 2.45 | 3.55 | 2.7 | 7. |
| Lime | 1.4 | 13.23 | ..... | 2.1 | 4.2 |
| Magnesia | 2.81 | 3.75 | ..... | 3.2 | 2.6 |
| Iron | 47.025 | 44. | 51.1 | 49.7 | 58. |
| Phosphorus | .06 | .045 | 0.8 | 0.078 | 0.5 |
| Sulphur | ..... | .5 | ..... | 0.5 | trace |

In absence of absolute data as to the corrected volume of air actually delivered to the furnace, the following statement has been prepared, to show the approximate consumption of air at atmospheric pressure per ton of iron and per pound of fuel (engine measurement, with no deduction for loss) during the blast:

| | Tons of Fuel per Ton of Iron. | Air per Ton of Iron. | Air per lb. of Fuel. |
|---|---|---|---|
| 1881 | 1.46 | 235,771.8 cubic feet. | 72.1 cubic feet. |
| 1882 | 1.4 | 220,429.4 cubic feet. | 70.3 cubic feet. |
| 1883 | 1.2875 | 202,821.1 cubic feet. | 70.3 cubic feet. |
| 1884 | 1.2875 | 201,610.1 cubic feet. | 70.4 cubic feet. |
| 1885 | 1.0875 | 192,094.0 cubic feet. | 78.8 cubic feet. |
| Average per blast | 1.3 | 209,947.5 cubic feet. | 71 9 cubic feet. |

It seems unnecessary to present any theories to emphasize the statements above given; but in addition to the interest in the conditions which caused so much annoyance to the manager, but which were finally mastered, the paper offers ground for discussing the possibilities of blast-furnace output, which appear to the writer to be much in advance even of the superior practice of many of our furnace-managers.

Naturally fine ore or decrepitating anthracite are often quoted as the causes of the "dirt troubles"; but these were not apparently lessened when the furnace was using all coarse stock, and it is doubt-

ful if the decrepitation is noticeable in coal which occupies nearly twenty hours in passing from the tunnel-head to its temperature of combustion at the tuyeres.

No more interesting study can be offered than a critical comparison of results obtained at some of the American blast-furnaces using different fuels, ores and fluxes, and equipped with various blast-heating appliances. To intelligently consider the subject, those comparisons should embrace similar data to those given in our *Transactions* of the operation of the Durham and Warwick furnaces. The results should be considered in their relation to the size of the blast-furnace, its dimensions and cubical contents; the fuel used; the yield of ore, and the percentage of flux demanded; the temperature and volume of blast required; the amount of air required per pound of fuel or per ton of iron; the quantity and grade of iron produced; and the duration of the campaign. With such data we may arrive at some practical estimate of the value of different fuels, of the importance of height of furnace to product, of the relation borne by the output to the cubical contents of the furnace, of the actual value of high temperatures of blast; and it is hoped that this paper may encourage the presentation of other comparative data showing actual results obtained.

It is believed that the results obtained at Warwick furnace during the long blast are not excelled even by furnaces of greater height, using richer ores or higher temperature of blast; and comparisons such as above suggested will be welcomed as showing the progress made in American blast-furnace practice.

## Discussion.

Edgar S. Cook, Pottstown, Pa. (Communication to the Secretary): Before the conclusion of the blast terminating September, 1885, I had been repeatedly requested by those more or less acquainted with the operations of the Warwick Furnace, to give the results of my experience. During the repairs of the furnace these requests were repeated. Not having the leisure to devote to the preparation of a paper for the Institute, I entrusted to Mr. Birkinbine all my notes, data, and drawings. He was familiar with our workings from frequent visits, and, with the help of diaries, has been enabled to supply everything of interest connected with the blast.

As to any conclusions that may have been reached, it is hardly safe to put them in print or even in words, since the results of the

next few months may change them altogether, as has happened repeatedly in the past.

The causes for the irregularities termed "dirt troubles," are to be found, I think, in the rapid enlargement of the bosh directly above the tuyeres, and extending upwards 10 feet or more. With heavy walls, varying in thickness from 36 inches to 48 inches, this enlargement proceeds very rapidly, by the melting of the brickwork under certain conditions of management, low fuel and fair yield of iron.

The furnace thus becomes very much out of proportion, the inwall portion increasing in size by wear but a trifle in the short time that is required for the melting away of the bosh-walls. Unless this enlarged space above the tuyeres is utilized by an increased volume of blast, ore-sand accumulates on the walls, reducing the size of the furnace, proportionate to volume of blast. If this filling were permanently fixed no serious results would follow, provided it were uniform and became hardened and worn to a smooth face. With this reduction in size, however, or a restoration of proper proportions, the furnace works grayer, and becoming hotter, soon cuts away the lower part of the ore-dirt accumulation; and in a twinkling the whole mass is precipitated into the crucible. The furnace is immediately overburdened, and if the quantity be very great, extending 6 or 7 feet above the tuyeres, a chill is likely to follow. Occasionally this ore-dirt or sand can be removed through the tuyere-openings and replaced with fuel and clean stock from above; but oftener the mass in the vicinity of the tuyeres becomes pasty and sticky, defying all efforts to bar and shovel it out.

If the equipment of boilers and engine is sufficient to permit of an increased volume of blast proportioned to the enlargement of the bosh, then by reason of the limited capacity of the furnace above the bosh, the stock is melted faster than it can be reduced.

Of course these observations are applicable primarily to furnaces constructed like the Warwick, with a total height of 55½ feet, but an actual working height of only 49 feet to the stock-line. This necessitates a reduced volume of blast and slower melting; and the manager is thus placed between the two horns of a dilemma, and in the early part of the blast is but little better off than if he had not the facilities to increase the volume of air.

If the furnace can be continued in operation sufficiently long, the in-walls wear away, increasing the size of the reducing part of the furnace. The proportion that should exist between the upper and lower sections is approximately reached again and permits the use

of a larger volume of air, which in turn helps to reduce the size of the accumulation, and thus necessarily lessens the risk of operating the furnace.

The use of coke seems to alleviate the trouble, even in the proportion of one-fourth coke to three-fourths anthracite. With a larger proportion it is probable that no serious difficulty would be experienced. The reason is doubtless to be found in the facility with which the blast penetrates the contents of the crucible with coke as fuel, the same volume of air keeping a much larger area active than is the case with anthracite. The only result from enlargement, using all coke or largely coke, would probably be poorer economy in fuel per ton of iron produced. My experience has been confined to anthracite work, never using more than one-fourth coke.

At the time when 1¾ to 2 tons of coal were used to make one ton of iron, such troubles as are here described were unheard of. Bosh-walls 4 to 5 feet thick were then the rule. Unless the furnace became scaffolded, the walls were cut away slowly, or if rapidly, they were as rapidly replaced by a carbonaceous or graphitic covering, which was far more durable than fire-brick. Irregularities frequently occurred, possibly similar to our dirt troubles; but, with the excess of fuel present, they passed off without attracting particular attention. With the fuel-consumption running 1 to 1¼ ton per ton of iron, the difficulties attending furnace-management are materially increased. Irregularities that under previous conditions attracted little or no attention produce serious results, with much less fuel in the furnace and faster driving.

Some six years ago, when I had my first experience with the irregularity termed "dirt trouble," it was, to me, entirely novel. I diligently enquired in person and by letter, in all directions, but could find no similar experiences elsewhere except in one instance, that of Mr. Charles Foote, then manager of the Crown Point furnaces, New York. Within the last year or two I understand that several anthracite furnaces have passed through similar trials. As others reduce their fuel-consumption and increase their product of iron, it is possible that the list may be increased.

I tried numerous mixtures of ores (running for a month at a time on all lump-ore to see if fine ore could have caused the trouble); but with no apparent benefit. It is probable, however, that with certain ores these troubles may not arise under any conditions.

My object in giving publicity to the operations of the Warwick furnace and the conclusions that I have arrived at, is to draw

forth expressions of opinion from those skilled in blast-furnace practice, with the view of having the phenomena described fully analyzed.

If "eternal vigilance" is the price of liberty, it would seem to be equally the price of success to the furnace-manager. Constant and close application is the best remedy, or rather the best way I have been able to discover to contend with the "dirt troubles;" and even then the chances at times are very much in favor of the dirt.

Since blowing in, December 12th, 1885, with 8 feet 9 inch crucible and 18-inch bosh-walls, we have averaged about 80 tons of iron per day, reaching 657 tons in one week, as the largest yield with 50 per cent. ore up to present writing. Our ore mixture has averaged about 48 per cent. iron, and our hot-blast 925° F. The fuel-consumption per ton of iron has been 1.1 to 1.25 tons. Instead, however, of being relieved from "dirt troubles," we encountered them in the second or third week of the blast, instead of the eighth or ninth as before. The reason is to be found in the fact that the furnace was blown in with about the size that the crucible had attained in the previous blast, after running eight or nine weeks, by the melting of the fire-brick. Unfortunately the stack is not high enough to permit the blowing of a sufficient volume of air to keep the entire crucible active. The difference in cost between anthracite and coke renders it unadvisable from an economical point of view to use more than 25 per cent. of the latter. So far, the trouble has not assumed serious proportions, having affected particularly the fuel-consumption and the grade of the iron. As the inwall enlarges by wear, I am in hopes that the difficulty will disappear altogether, or at least to such a degree as to leave no cause for anxiety.

W. J. TAYLOR, Chester, N. J. (Communication to the Secretary): One important feature in Mr. Cook's work is the rapidity with which he drives stock through the furnace, although it has only about 5500 cubic feet capacity. I think there is no instance on record of an anthracite furnace doing good work and yet cleaning itself in so short a time as twenty hours, which is about what Mr. Cook is doing now (February, 1886); as he is driving through from 110 to 120 charges of 2000 pounds fuel-base within twenty-four hours, while the furnace will hold only about 80 such charges. This is about as fast driving as has ever been done with coke, and compares very closely in every respect with the work of the Isabella furnace, Pittsburgh, which makes 220 tons per day, using coke for fuel. The Isabella furnace is charging, say, one ton of material daily for each

17.1 cubic feet of capacity, and Warwick furnace does the same for, say, 17.5 cubic feet. The Isabella furnace, with a 56 per cent. ore, is making one ton of iron per day for, say, each 68.2 cubic feet of capacity, and Warwick furnace, with a 50 per cent. ore, one ton of iron for, say, each 70 cubic feet of capacity. Comparing this with any other anthracite record, we find a great difference. In my practice I have never been able to do good work on anything like this driving.

A twenty-weeks run of the Chester furnace in 1881 shows good results in every respect excepting speed. The furnace was 13 feet in diameter at bosh and 60 feet high. It was blown by four 4-inch tuyeres. The average daily make, 33.82 tons No. 2 and No. 3 iron—about half of each number; the average consumption of fuel ($\frac{1}{1.0}$th to $\frac{1}{1.2}$th coke), 1.241 tons per ton of iron; the yield of the ore, 47.80 per cent.; limestone per ton of iron, 0.909 ton; average temperature of blast, 775° F.; average volume of air per minute (engine measurement), 5480 cubic feet.

The capacity of the furnace was then 4340 cubic feet, so that we charged only 1 ton of material for every 30 cubic feet, and made 1 ton of iron per day for every 128 cubic feet.

In the case of Mr. Fackenthal, at the Durham furnace, the difference is also very great. This furnace has about 15,000 cubic feet capacity, or is over two and a half times as large as Warwick, yet the Durham furnace passes only a trifle more stock through it per day, say 10 to 20 per cent., than is consumed at Warwick furnace; so that at Durham furnace the stock is exposed to the action of the gases more than twice as long as at Warwick. Yet both are doing extraordinarily good work in fuel-consumption, showing that reduction can be accomplished in, say, 20 hours just as well as in 40 or 50, *provided the conditions are right.*

I append a tabular statement of the blast at Chester furnace to which I have referred.

*Record of the Operation of Chester Furnace, N. J.* (13 *feet* × 60 *feet*), *for a Blast of Twenty Weeks, from February* 17*th*, 1881, *to July* 9*th*, 1881.

| Weeks. | Pig Iron made. Gross tons. | Yield of ore. Per cent. | Used per ton of iron. | | Blast. | | | Temperature of escaping gases. | Weekly stoppages. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fuel. Gross tons. | Limestone. Gross tons. | Temperature. F. | Pressure in lbs. | Cubic feet of air per lb. of coal. | | Hours. | Minutes. |
| 1 | 211 | 45 | 1.43 | 1.18 | 770 | 7.45 | 74.87 | 320 | 2 | 30 |
| 2 | 232 | 47 | 1.347 | .946 | 788 | 8 | 72.03 | 333 | 3 | 13 |
| 3 | 244 | 51.2 | 1.164 | .94 | 737 | 8.28 | 80.97 | 422 | 4 | 05 |
| 4 | 261 | 49.3 | 1.197 | .94 | 763 | 8.17 | 76.61 | 412 | 4 | 10 |
| 5 | 242 | 46.2 | 1.28 | 1.11 | 783 | 7.92 | 74.66 | 361 | | 49 |
| 6 | 237 | 47 | 1.258 | 1.00 | 746 | 7.35 | 76.81 | 388 | 5 | 14 |
| 7 | 239 | 46.8 | 1.28 | .95 | 724 | 7.56 | 76.29 | 415 | | 55 |
| 8 | 241 | 48.3 | 1.217 | .89 | 746 | 7.75 | 79.40 | 412 | 2 | 46 |
| 9 | 246 | 49.3 | 1.15 | .868 | 729 | 7.85 | 80.35 | 439 | | 59 |
| 10 | 247 | 50 | 1.126 | .867 | 730 | 7.47 | 82.51 | 416 | 2 | 30 |
| 11 | 242 | 49 | 1.175 | .898 | 754 | 7.59 | 80.84 | 430 | 4 | 53 |
| 12 | 239 | 47.6 | 1.191 | .824 | 744 | 7.60 | 82.58 | 424 | 1 | 23 |
| 13 | 239 | 48.2 | 1.184 | .753 | 742 | 7.74 | 82.52 | 448 | 7 | 13 |
| 14 | 237 | 46 | 1.292 | .79 | 735 | 7.69 | 78.43 | 449 | 5 | 28 |
| 15 | 228 | 44.6 | 1.305 | .81 | 766 | 7.21 | 82.67 | 469 | 1 | 25 |
| 16 | 236 | 48 | 1.222 | .745 | 783 | 7.57 | 84.04 | 444 | 4 | 13 |
| 17 | 236 | 49.5 | 1.188 | .772 | 788 | 7.41 | 83.39 | 449 | 3 | 10 |
| 18 | 233 | 47.8 | 1.23 | .90 | 794 | 7.44 | 83.16 | 439 | 3 | 55 |
| 19 | 217 | 47.2 | 1.305 | .986 | 778 | 7.58 | 82.26 | 443 | 2 | 32 |
| 20 | 192 | 47.6 | 1.283 | 1.01 | 808 | 7.58 | 82.65 | 449 | 23 | 43 |
| Av'ge. | 236½ | 47.8 | 1.241 | .909 | 760.4 | | | | 4 | 15 |

F. W. GORDON, Philadelphia (Communication to the Secretary): The difficulties encountered by Mr. Cook call to mind Mr. W. J. Taylor's work, at Chester, N. J., with a "no-bosh" furnace, in which the accumulation of this "dirt" formation above the tuyeres was experienced. The statement that Mr. Cook's experiences are new developments in iron-making, will bear criticism. He has better developed the nature of these troubles; but they are, I think, quite the rule rather than the exception in anthracite practice, and constitute a great, if not the whole, difference in working between that fuel and coke.

Mr. Birkinbine has not endeavored to point out how these "dirt" accumulations are formed, much less the way to avoid them; and the great importance that this question must have to the Eastern iron manufacturer will justify much speculation and theorizing. The East is dependent upon the West for coke, entailing costly carriage; and yet, in a calorific estimate of value, the coal is as good as the coke. If the formation of dirt troubles can be practically avoided,

anthracite will be found to smelt almost as quickly and quite as economically as coke, and, I believe, with but a slight increase of blast-pressure.

Mr. Taylor sought to remedy the evil by reducing the furnace-diameter and so obtaining a direct pressure from the tunnel-head to the tuyeres, to cause active action of the full area of the furnace. The result was that bad matters were made worse. His furnace, previously 13′ bosh and 6′–6″ hearth, though experiencing troubles of this kind, had suffered nothing so serious as the straight or "no-bosh" furnace did. Mr. Cook has enlarged his hearth from 7′–5″ to 8′–9″; and this might seem to be following the theory that prompted the doing away with boshes altogether. This degree of enlargement, however, may be effectual; and he may succeed, though working in the same direction in which others failed, for reasons hereinafter alluded to, which may limit the diameter of the hearth, and which, if correct, would indicate that Mr. Cook is possibly nearly right for his late most excellent working.

In blowing in this anthracite furnace on the three different occasions recorded, it is to be noted that for nine or ten weeks the work was satisfactory in every respect. At the end of that period "the bosh was gone for ten feet up;" its place was filled with "dirt" consisting of fine coal, ore, and limestone; and the troubles commenced—which means that the space cut away from the boshes was filled to overflowing with this dirt. The manager undermined this accumulation by withdrawing the tuyeres, and he now proposes to leave out the shelf which formed its support. This is a most natural action; but in the first place, would it not have been better to prevent the cutting away of the bosh in the dish-form exhibited in the drawings, where such accumulations collected? It would seem that the prevention of these collections of dirt is all that is now aimed at. It should be the prevention of the causes of its formation, if such be possible.

When the furnace was first filled and blast put on, the boshes cut fully, *proving that the gases sought the walls too freely, avoiding the less free passage through the mass of stock.* This intensity of temperature would rapidly extend itself upward, still keeping in the freer passage next the walls, and heating the newly charged anthracite with great rapidity, and would decrepitate it *next the in-wall only.* This fine anthracite descending along the walls and carrying with it ore and limestone, being but small in quantity, would not in descending obstruct the continuous upward flow of the

gases next the in-wall. This material would gradually grow in bulk upon or in the dish formed by the cutting of the boshes. As these accumulations increase at their lower point, being held upon a shelf of fused or semi-fused materials, the blast is deflected more to the center of the hearth, but, hugging close to the formation, soon spreads back to its passage next the walls and continues the evil. When the accumulation becomes excessive, it may come away in large quantities and give serious trouble in the hearth. This, however, supposes that the passages next the walls were too free at first, and this excess of freedom never was destroyed from, say, mid-way of the in-walls up. The currents of gas passing close by the accumulations on the boshes seek the walls at as early a moment as possible, according to the height to which these accumulations may extend.

This view is entirely at variance with the idea of a scaffold being formed on blowing in. It requires the abandonment of such a thought at once; but I think it will explain the "no-bosh" difficulties, the desirability of boshes, and the necessity of limit to hearth dimensions when using anthracite fuel. The same reasoning may be applied to coke-furnaces with equal truth, but not with so much force.

The "no-bosh" form permits freer currents toward the in-walls. The blast is introduced almost in a line with them at the commencement of operations, and ascending in straight lines without meeting any serious resistance, produces great mischief with extreme rapidity. Decrepitated coal in large masses may be formed before the direct current is obstructed, and when these masses reach the region of the tuyeres, or a little above it, full trouble may be established. As these troubles or accumulations became extensive, the blast would certainly be diverted into the center of the hearth; but, as before remarked, it would return again to the in-walls and continue the formation of these accumulations.

The "first short blast" difficulties of Mr. Cook may be explained as above, with this difference, that these accumulations formed on the boshes in a great mass before moving, and then, coming away at once, slipped to the bottom toward the center of the furnace. If this latter supposition be correct, the bridge must have been thicker on the walls than in the center of the furnace. This furnace was evidently better under control with the tuyeres drawn back; and the reason seems to be, not that the formation was prevented, but that its *accumulation* was avoided. Yet this accumulation was

not avoided in the "no-bosh" furnace, under what would seem to be better conditions than Mr. Cook had with his tuyeres withdrawn; and some explanation must be found for so apparent a contradiction if my theory is to be accepted. That in an 8′ furnace with a 7′ hearth, dirt would accumulate above the tuyeres with extreme rapidity, while a 15′–6″ furnace with a 8′–6″ hearth would work with but little trouble from this cause, argues that an increase of hearth should have no influence on its removal. The difference to be noted in these two furnaces is that the "no-bosh" furnace received 3400 cubic feet of air per minute, and the Warwick 9000 cubic feet.

Assuming that 74 cubic feet of air were given per pound of fuel consumed (the average as per tables), we have a fuel-consumption of 46 lbs. per minute in the "no-bosh," to 109.8 lbs. in the Warwick. Referred to the hearth-area, this is 1.14 lbs. per square foot hearth-section in the "no-bosh" to 1.93 lbs. in the Warwick. (Ten per cent. is deducted in the last calculation for the assumed amount of carbon burnt in the zone of reduction.) The heat generated by the combustion of a unit of carbon in the "no-bosh" furnace would not have exceeded that due to CO, namely, 2400 calories, while at the Warwick it would not fall short of 3500 calories. Now, as all the heat generated in a blast-furnace will finally reach the hearth, except that escaping as sensible heat in the gases, and by radiation through the walls, the quantity of heat reaching each hearth per square foot of section would be for the "no-bosh" $2400 \times 1.14 = 2736$ calories; for the Warwick, $3500 \times 1.93, = 6755$ calories; a ratio of 1 to 2.47. The temperature developed in the two hearths may vary from this ratio inversely with the quantity of the materials entering each hearth per unit of time and cross-section, the blast being of an equal temperature in both cases. Though Warwick had more iron and slag entering the hearth with fuel, yet the "no-bosh" had much more unconsumed fuel passing into and sometimes through the hearth, which was not pre-heated in the upper portions of the furnace, the gas passing directly away instead of performing this most important regenerative action of the blast-furnace. This, perhaps, obstructed more heat than Warwick's heavy quantities of iron and slag carried away as they were flushed. It is not much out of the way to say that the "no-bosh" hearth had not over 40 per cent. of the temperature of the Warwick hearth, averaged throughout its section; and in this view of the matter it might be expected that but little burden would be required to chill this furnace and render a

make of white iron all that could be accomplished. Had this "nobosh" furnace been blown with 7000 cubic feet of air (the full capacity of the engine), much less difference would have been experienced between its action and that of the Warwick, so far as accumulations of dirt would represent trouble in the hearth; though I am persuaded it could not have been economically operated as a blast-furnace.

Touching the question of the temperature of the hearth, which I believe limits its dimensions, did Mr. Cook do well to withdraw his tuyeres and work with a hearth of say 8′–6″ diameter, leaving out for the time being the necessity for doing so to allow for the continual flow of dirt? I would say he did; and we have by his work a possible limit to economical hearth-dimensions rated on a given total combustion and with his temperature of blast. *For we find that the fuel decreases with an increased volume of blast, reaching wonderfully economical results, temperature of blast, cubical contents of furnace, ore and limestone used, being considered.*

It is a pity, for the sake of the science of the blast-furnace, that the quantity of blast blown had not been still further increased, when the absolute demonstration of the point of highest economy under his conditions would have been established. This question has been somewhat studied by Mr. Potter, of Chicago, and he has informed me what he considers his economical limit of volume of blast. This reduces the fuel-consumption within the furnace, and very closely accords with the late work of Mr. Cook, due allowance being made for the temperature of blast and the character of materials treated.

I conclude that Mr. Cook's hearth was too large for the blast he used when he first withdrew his tuyeres, and the temperature required in the hearth was supplied by a reduction of burden; and that afterwards a more rapid combustion per unit of area and local intensity of temperature permitted the increase of burden to a limit consistent with rapid deoxidation. Yet, in this latter case, more iron was made and greater rapidity of reduction effected, with a leaner gas. In other words, he must have formed, by the increased intensity, a better localized temperature and a more healthy zone of reduction; but had this blast been still further increased, the evils in an opposite direction would soon have presented themselves, to which extreme many of our coke-furnaces have proceeded.

After touching upon the possible manner of the formation of the dirt and trying to explain the *seeming* contradictions in the action of the different furnaces, it will be in place to offer a suggestion for the

prevention of this serious difficulty. If the decrepitation of the anthracite coal is the chief cause for this accumulation, the remedy would seem to be in slowly heating this fuel after it enters the furnace. If it only forms next the in-wall and there by the local excess of temperature, while otherwise throughout the furnace the heating is sufficiently gradual, a remedy would be to check the flow on the walls; while, if the excess of heat diffused from the wall would make the whole area dangerously hot, a larger and higher furnace, securing a cooler gas, would be required. We have seen at the Warwick a 5′ bell to a 10′ top impairing the efficiency, while the *seeming* dirt troubles were not augmented. I have underscored "seeming," as the excess of fuel required would indicate that the amount of dead stock going into the furnace-hearth was in excess of what it previously had been with the 7′ bell, that is, with a smaller bell the trouble was augmented. The dirt found on the bosh-wall while the 7′ bell was in use, contained 47.6 coal and 47 of ore, showing much less ore than the proportions charged of ore and coal. This would seem to show that the 7′ bell was still too small.

I propose a bell so enlarged that the ores will be deposited upon the walls, so as to force the currents of gas more toward the center, but not absolutely drive them from the walls. This, in the Warwick furnace, may be accomplished in three ways. An enlargement of the bell continuing the same charge; an enlargement of the charge with the same bell; and enlargement of charge and bell. To establish the best currents of the gases of coke-furnaces, I have followed the work and best practice of a great many furnaces, and find that when the ore is charged alone, a quantity not less than that which would be equal to a ring 12″ thick, covering the annular space between the bell and the in-wall, is sufficient. When, however, the ore and fuel are charged together, one-half of this burden will suffice, as the fuel will carry the ores toward the in-wall. I do not think this latter proposition would be true in anthracite practice, as the smaller bulk of fuel would not carry out the ores so well, and larger charges in proportion should be used. I prefer charging ore and limestone alone, and would charge in the Warwick furnace not less than 6000 pounds of ore at one drop of the bell. It might be much more convenient for them to use a bell say 7′–9″ with about their present charge. It is noticeable that the Durham furnace, referred to by Mr. Birkinbine, working at times on all anthracite fuel, seems to have no trouble from this dirt. In Mr. Fackenthal's paper on that furnace, he especially mentions the extreme regularity of the blast-

pressure and of the working of the furnace. This furnace possesses what I have given above as the requirements to prevent the formation of this dirt, namely, large cubical contents, large bell and heavy charging.

MR. COOK (A second communication): Mr. Gordon's comparison between Mr. Taylor's "no-bosh" furnace and Warwick is interesting; but in my observation of the former during a short visit while it was running, I was not able to notice any resemblance whatever in the working of the two furnaces.

I have known of several instances in which "dirt troubles" were occasioned by the decrepitation of anthracite coal, and one case in which similar difficulty was produced by a soft or easily friable coke. During the 5-year blast, we used essentially the same coal each year, our supply being shipped from two of the principal collieries of the Philadelphia and Reading Coal and Iron Company. If the trouble had been due to the decrepitation of the coal, it would scarcely have grown less with each year of the blast, until finally it was reduced to a minimum. There is certainly more or less decrepitation, but not sufficient to account for "dirt trouble." It is chiefly due to ore. With the same ore-mixture, the same number of charges per 24 hours, and the same burden, each cast would naturally give about the same number of tons of iron, the condition of bottom and iron-notch being the same. But at times the ore-dirt is deposited on the walls rapidly, as is evidenced by decided shortage of iron at certain casts, which casts are far grayer than the average. After such times, as the dirt loosens and reaches the crucible, the casts become considerably larger than the average, and of closer grade. Of course, similar variations may arise from other causes; but other attending circumstances prove the correctness of my supposition.

In any furnace working normally, the ore below the bosh will be found in the condition of fine powder or sand, whatever may be its physical condition when filled. The *formation*, then, of the ore-sand of our "dirt troubles" is natural enough. To my mind the problem to be solved is the prevention of its dangerous accumulation. Mr. Gordon's suggestion of larger bell and larger charges may be valuable and worthy of trial; but I doubt whether it would accomplish the desired effect with a furnace in the shape of Warwick during the year 1881.

If it were possible to determine the proper proportions of a furnace, taking into consideration the character of the ores and fuel to be used, and then build so as to retain these proportions, I do not

think the "dirt-trouble," as I have known it, would present itself as a menace to the furnace-manager. At the same time, a similar trouble may easily be produced in any furnace, however well it may be proportioned, by excessive and continued over-blowing or over-driving in connection with over-burdening.

---

## *THE MINING COMPASS AND TRIGONOMETER.*

BY ERICH G. GAERTNER, NEW YORK CITY.

ALMOST every mining engineer who has had charge of extensive underground workings will have observed how often directions as to course and levels, deduced from careful theodolite measurements, have been slighted or disregarded by mine-foremen and shift-bosses, and how often these tedious measurements had to be repeated, even for minor works, such as ventilation-drifts or winzes, in order to carry them on with the required or desirable regularity.

Besides the time and care absorbed by theodolite surveys, there is still another inconvenience, namely, the interruption of transportation during the time of observation, and, in heavily producing mines, the loss consequent upon such interruption.

In proposing a subsidiary instrument to the theodolite, it is my purpose not to present a new one, but simply to recommend to the consideration of American mining engineers one which has been in use in nearly all the prominent mines of Europe for many decades, and has there fulfilled its purpose admirably. I refer to the mining or hanging compass (Fig. 1).

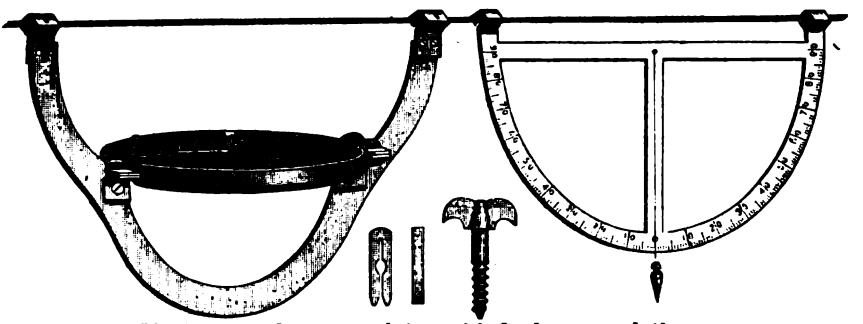
At my urgent request, the firm of Keuffel & Esser, of New York, have lately constructed this instrument in a form which adapts it better to use in this country. By the addition of the trigonometer, the hanging compass becomes at once an instrument which will prove of value even in the hands of foremen and practical miners, who have little or no knowledge of trigonometrical calculations.

Probably many will say that we have no use for needle-instruments; that our modern theodolites are of such perfect description, and leave so little to be desired, that the introduction of a compass would look like a step backwards compared to the fine results obtained by angle-instruments. I concede all that, and do not pre-

tend that the accuracy of the hanging compass is equal to that of the theodolite, or even sufficient for close measurements.

But as an auxiliary, especially in irregularly worked mines, where frequent approximate surveys are desirable between the more formal

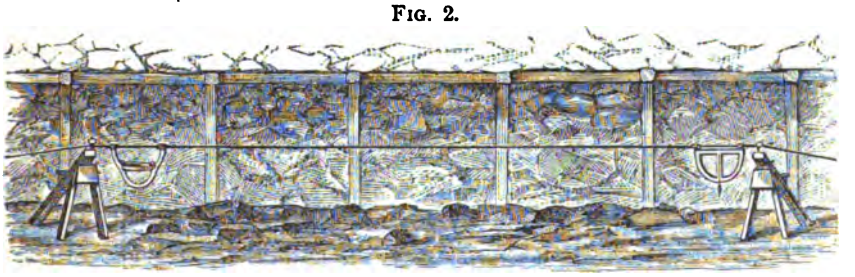
FIG. 1.



The Hanging Compass and Arc, with Cord screw and Clamp.

and precise ones, it certainly has an important use. Even in mines where local attraction would affect the needle, I do not see why the angle of two adjoining courses might not be taken by observing on both sides and close to the apex. The variation of the needle, under

FIG. 2.



Method of Using the Hanging Compass.

ordinary conditions, even if caused by local attraction, is likely to be the same, if the points of observation are but a few inches apart.

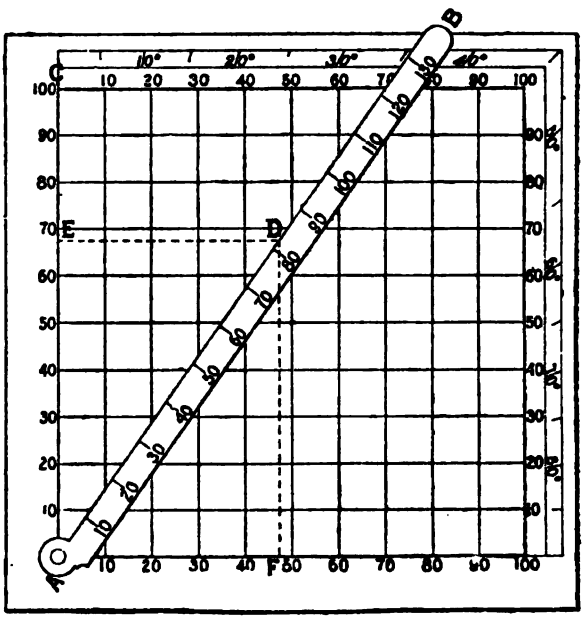
The hanging compass is constructed on the plan of a ship's compass, hanging level at all times, and giving the course by means of a stout cord from which the frame is suspended. The graduation is in quadrants, as in most theodolites, instead of the European division into hours; and the vertical arc, provided with a plumb-line of fine silk, allows a direct reading to quarter-degrees and an approximation from five to ten minutes. The manipulation of the instrument (Fig. 2) is extremely simple: stretch a cord from brass screws

fastened either in the timbering of the mine or in wooden bucks provided for that purpose, and read courses as well as vertical angles by suspending the compass and arc respectively from the tightly stretched cord.

The co-ordinates to horizontal and vertical angles can be easily obtained by the other instrument which I have mentioned, namely:

*The Trigonometer.*—A plate fifteen inches square (Fig. 3), representing a division horizontally and vertically into 100 equal parts, which are again divided into halves, is provided with an arm or alidade, AB,

FIG. 3.




The Trigonometer.

which, having the same division as the plate, is fastened with its zero-point upon the zero-point of the plate and moves freely around the same. A quadrant divided to quarter-degrees, and having this zero-point as a center, is graduated upon the plate. By moving the arm to the given angle, and reading the distance of the respective measurements on the arm, the co-ordinates are immediately obtained on the plate, with sufficient accuracy for the calculation of measurements as obtained by the hanging compass. If, for instance, BAC be the given angle, and AD the given distance, DE and DF are the co-ordinates. Again, if AE be the radius, and BAC the angle of

deflection, DE is the tangent; and so on, through all the trigonometrical functions. The readings are exact to within 0.1 per cent. A few hours devoted to the instruction of a foreman, will enable him, if possessed of ordinary intelligence, to carry out measurements from the base-lines established by the engineer, and save the latter much time, labor, and inconvenience.

---

## *THE CORNWALL IRON-ORE MINES, LEBANON COUNTY, PA.*

BY E. V. d'INVILLIERS, PHILADELPHIA, PA.

THE position of these magnetic ore-mines, with reference to the county-seat, is shown in Fig. 1. They are situated on the south margin of the Great Valley, five miles south of Lebanon, and about midway between Reading on the Schuylkill River and Harrisburg on the Susquehanna River, in three prominent, contiguous hills, standing in front of the Mesozoic red shale and sandstone hill country of northern Lancaster and southern Lebanon counties, and overlooking the great limestone plain to the north.

The three hills, named respectively Big, Middle, and Grassy Hills, and separated from each other by two branches of Furnace Creek, range in a nearly east and west direction for a distance of about one mile. Their summits are respectively 870, 715, and 700 feet above tide. The railroad line opposite the base of Middle Hill is 575 feet above tide at Cornwall and 471 feet at Lebanon.

These features are all distinctly illustrated in the contour-line map accompanying this paper, but are made still more clear in the relief. map, Fig. 2, comprising, as it does, about six square miles of territory contiguous to the ore-mines.

This is a photographic plate of a model made by Mr. A. E. Lehman, from surveys of my own and Mr. W. F. Shunk. The model was built in layers of cardboard, each layer representing one 10-foot contour-curve line. The scale was the same as the original map, 400 feet = 1 inch, without any vertical exaggeration.

The lowest contour-line is 530 feet above ocean level; the highest, 1075 feet. The center of the model was made the focusing-point of the view, which was taken—according to scale—5½ miles north from and 2½ miles above the focusing-point, looking southward.

When first mined in the last century these hills exhibited smoothly-rounded surfaces, composed of soft weathered ore of great purity, beneath which lay the great mass of hard ore, constituting the whole

FIG. 1.

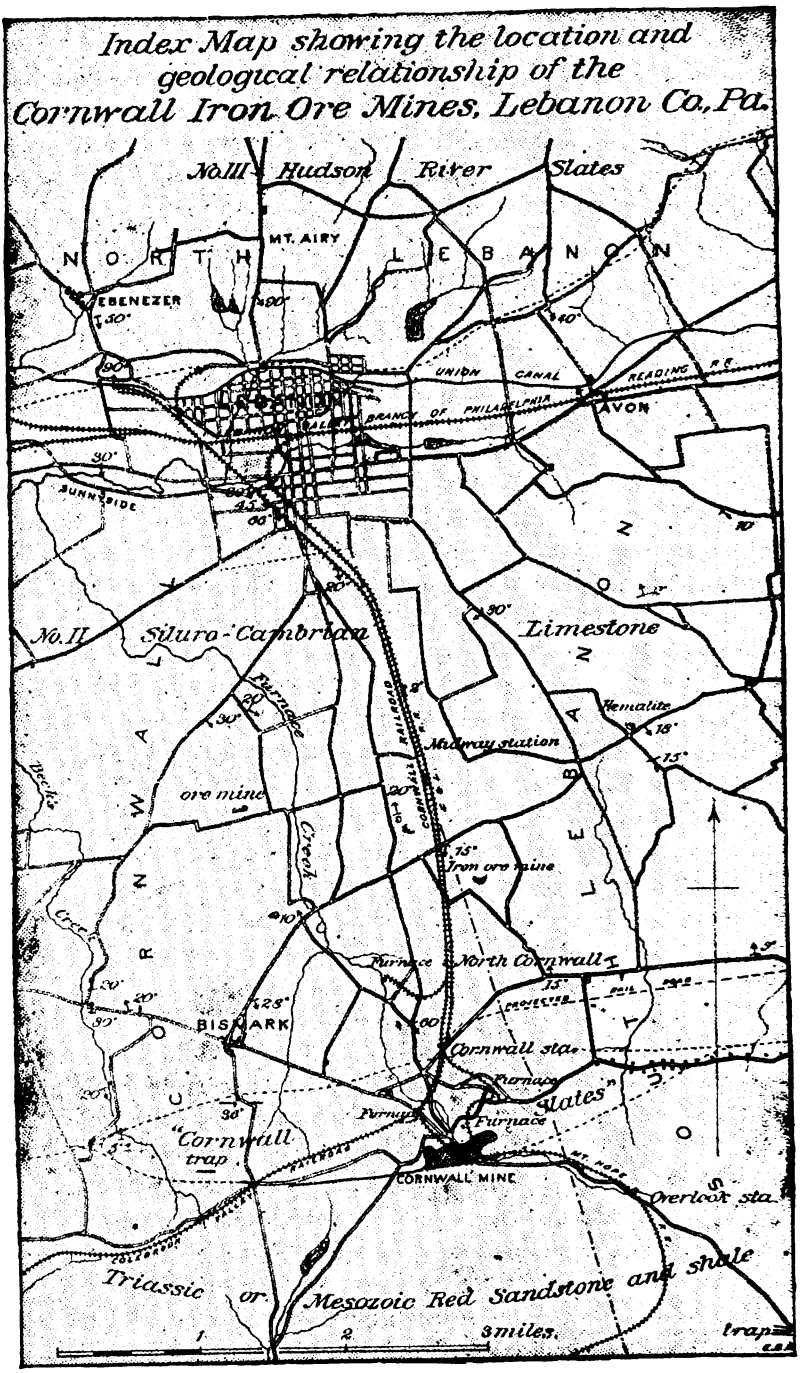
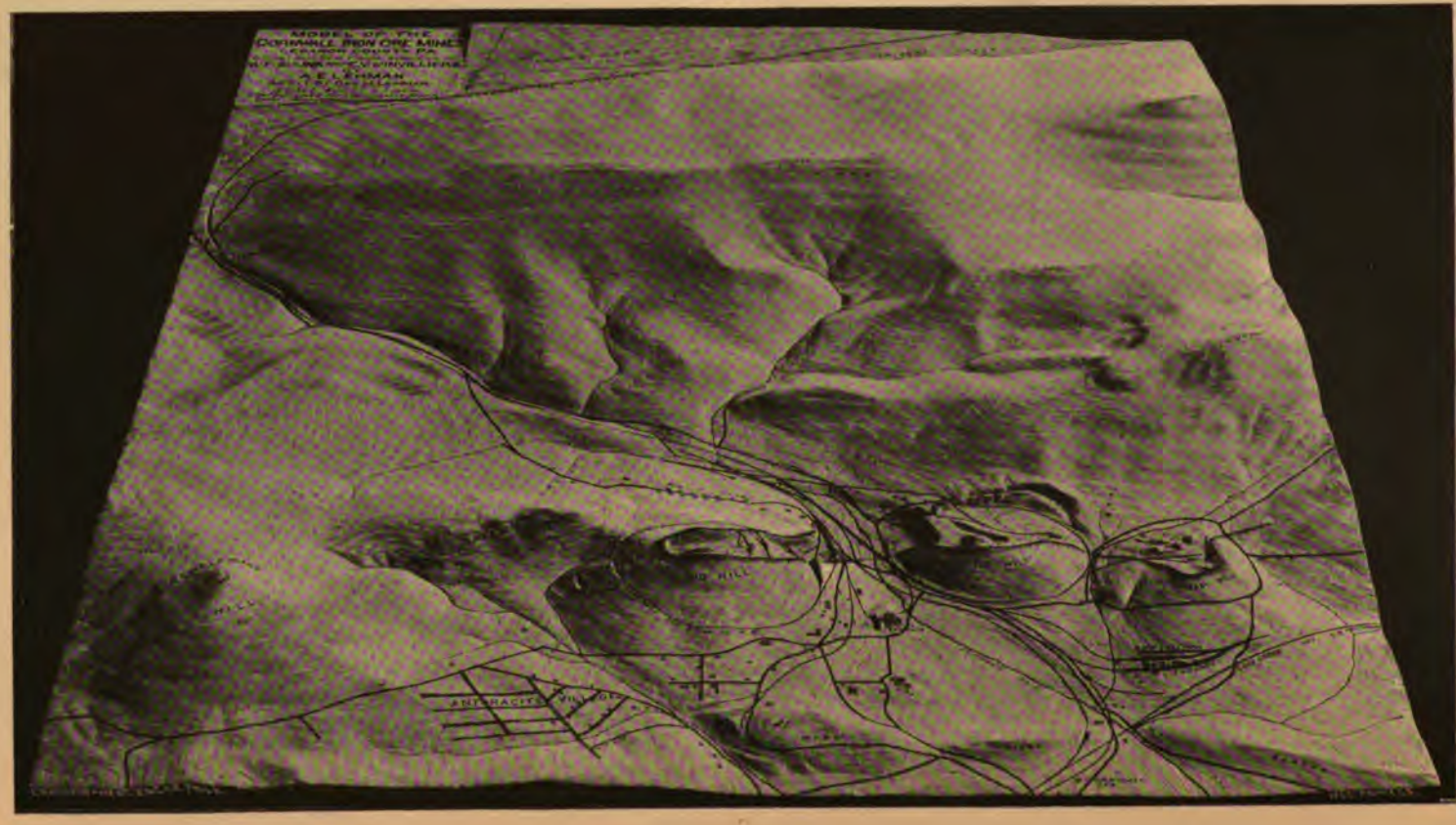

Index Map showing the location and geological relationship of the Cornwall Iron Ore Mines, Lebanon Co., Pa.
No. III Hudson River Slates
NORTH LEBANON
MT. AIRY
EBENEZER
UNION CANAL
READING R.R.
BRANCH OF PHILADELPHIA
AVON
SUNNYSIDE
No. II Siluro-Cambrian Limestone
Furnace
Midway station
Hematite
ore mine
Iron ore mine
North Cornwall Furnace
BISMARK
Cornwall sta.
Furnace
Furnace
Furnace
"Slates"
"Cornwall trap"
CORNWALL MINE
Overlook sta.
Triassic or Mesozoic Red Sandstone and shale
trap
1
2
3 miles.

FIG. 2.



body of each hill, now extensively removed by quarrying down to the water-level of Furnace Creek. But the quantity of ore still remaining above water-level is much greater than that removed, and in several places the original surface is still untouched, while beneath water-level the ore is known (by borings) to descend to a depth exceeding 300 feet.

The extreme length of the uncovered ore-deposit is about 4400 feet; its breadth in Big Hill about 400 feet, in Middle Hill 800 feet, and in Grassy Hill 600 feet; and its total area is estimated at nearly 63 acres. The north and west brow of Grassy Hill, the north brow of Middle Hill, and the north, east and south brow of Big Hill is an outcrop of dolerite trap. The sloping trap dike is exposed on the opposite sides of each of the two gaps, descending from the hill tops to water-level, with an apparent width of about 100 feet. Beneath water-level the trap dike is of course continuous from the east end of Big Hill to the west end of Grassy Hill, where bending towards the southwest it disappears beneath the Mesozoic rocks.

The ore-mass lies against the south sloping face of trap, therefore overlying and abutting against it. The rocks immediately north of the bounding wall on the hill-slopes are hidden by a mass of broken fragments of trap, so that very little is known of their character or position.

The edge of the ore-mass, as shown by the map accompanying this paper (see Plate), is by no means a straight line, but follows the irregular course of the trap, which changes several times in a very abrupt manner.

Big Hill is separated from the Mesozoic highlands to the south of it by the valley of Furnace Creek, which heads up about 1½ miles southeast of the mines, and descends from a notch in the Dividing Ridge (improperly called South Mountain here) through which the Cornwall and Mt. Hope Railroad passes, with a grade-level of about 845′ A. T., which corresponds closely with the elevation of Big Hill. The Dividing Ridge rises to about 1050–1075 feet A. T. on either side of the railroad, and has a general trend of about N. 58° E.

The northern slope is broken by a series of gullies, descending into Furnace Creek, which create subordinate ridges, all having about the same general direction as the main hill, and with but slight variation, containing rocks dipping at small angles 10°–20° northwestward towards the ore-hills and limestone-valley of Lebanon county.

FIG. 3.

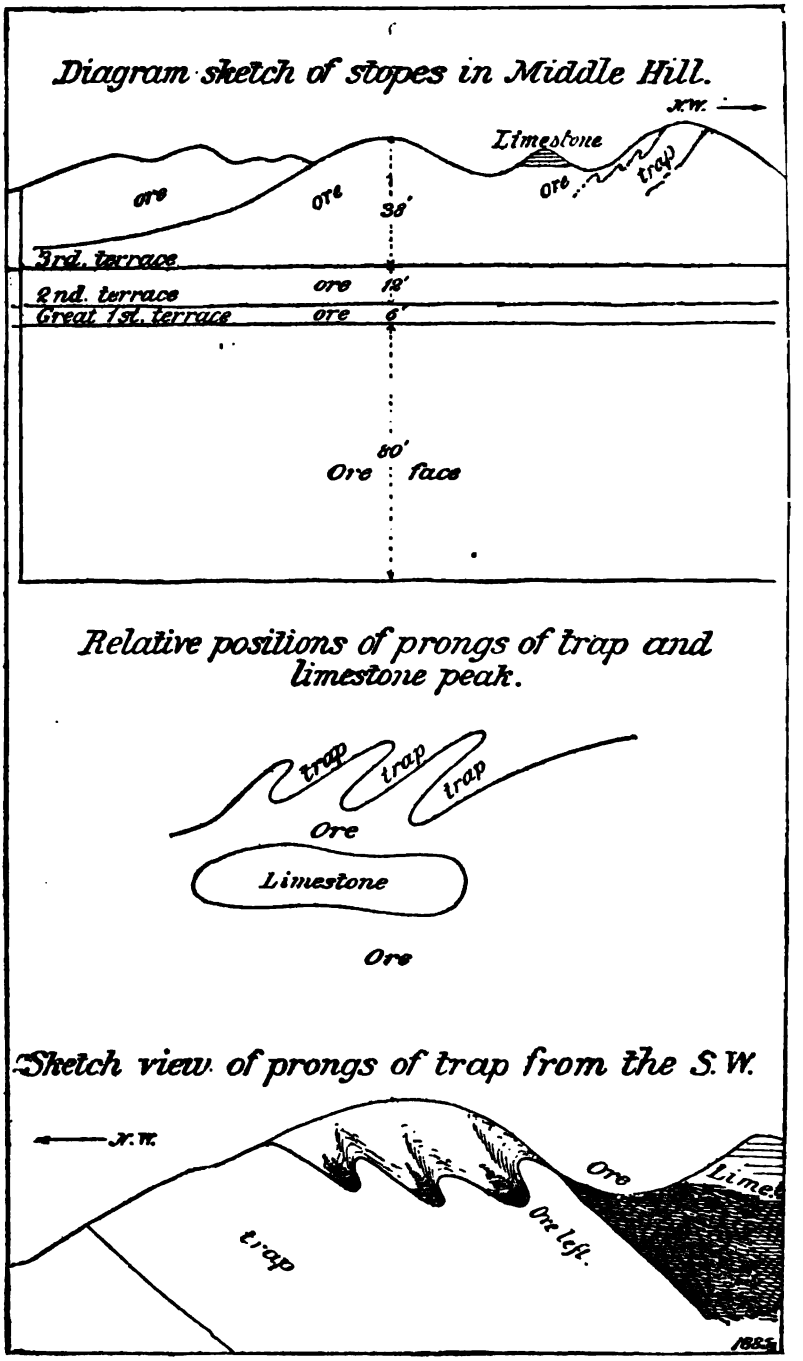


Diagram sketch of stopes in Middle Hill.
N.W.
Limestone
trap
ore
ore
ore
38'
3rd. terrace
2nd. terrace
Great 1st. terrace
ore
12'
ore
6'
80'
Ore face
Relative positions of prongs of trap and limestone peak.
trap
trap
trap
Ore
Limestone
Ore
Sketch view of prongs of trap from the S.W.
N.W.
Ore
Lime.
trap
Ore left.
1885

in which the trap was forced upwards through the ore-slates. The most remarkable point is, that this great outburst of lava shows no signs of having bent, displaced or affected in any way whatever the ore-strata which repose quietly against the surface as if against a previously established fixed wall. Another equally suggestive phenomenon is the formation of a complete hook of trap around Big Hill. This is at the east end of the mine, and has no corresponding hook at the west end. In other words, a hook was formed at the end towards which the ore-slate stratification rises, and not at the end towards which it dips.

The function of the trap has been eminently a preservative one, its hard rock resisting the general erosion of the whole region and preserving above water-level a portion of the ore-mass which otherwise would have been most probably swept away long ere this. It is not to be supposed that the trap had anything to do with furnishing the ore-mass with its iron, for deposits of similar ore exist elsewhere through this range, not apparently connected with trap in any way. Part of the trap has gone; how much cannot be known. Part of the ore has likewise gone, and probably a greater portion than has been preserved.

## II. The Cornwall Ore-Mass.

The Cornwall ore-mass is evidently a regularly stratified formation, sloping down southwestward against the edge of the Mesozoic rocks and rising northeastward into the air, where it is worn off on the top of Big Hill. As a consequence of this, any particular stratum on the summit of Big Hill will lie (topographically) very much lower in Middle or Grassy Hills, the amount of difference in elevation depending entirely upon the dip. And this may account for the great depth of ore (325′+ thick) found at bore-hole No. 4 in Middle Hill. This stratified formation has been in some manner converted into ore, retaining its place and form in all essential particulars.

Whatever this process was, its effects at Cornwall are precisely like its effects at the Wheatfield, Island mine at Reading, the Boyertown magnetic ore-mines in Berks county, and the great brown-hematite mines in Centre county and elsewhere.*

What first strikes the observer in entering these mines through the valley of Furnace Creek is the unusual depth of the deposit still

* See author's reports D 3, vol. ii, and T 4, Geological Survey of Pennsylvania.

remaining above water-level, the terraces of Big and Middle Hills being very impressive. The water-plane of the mine is about 570′ A. T.; the stopes or terraces rising from this.

In Big Hill the stopes are respectively 40′, 120′, 50′ and 70′, measured from below upwards, the highest point of ore, the present summit of Big Hill, being 300 feet above the water-plane between Big and Middle Hills.

In Middle Hill the first stope rises from the water-plane 80′, with a length of 500′ measured along its top edge from the trap wall to the entrance of the great "Water-Level Cut," which is designed to penetrate westward to Grassy Hill.

The first terrace is 200 feet wide to the base of the second stope, which is 6 feet high. The second terrace is 30′ wide to the third stope which is 38 feet high, to the original hilltop. See Fig. 3.

Middle Hill has been worked back westward from the creek 450 feet to the foot of the first stope. In November, 1885, the Water Level Cut before mentioned had extended this distance to 600 feet; the height of the ore being then 60 feet in this cut.

The depth of the ore-mass beneath the water-plane near the creek was tested by three bore-holes, marked No. 1, No. 2, and No. 3 on the map, No. 1 being furthest north and within 140 feet of the trap, which it struck at a depth (all ore) of 134 feet. No 2 is 100 feet from the last and struck the trap at 179 feet. No. 3 is 275 feet further south and met the trap at 238 feet.* All three holes were started upon the same level and went through the same stratification of ore. Bore-hole No. 4, 1440 feet S. 76° W. of No. 3, 150 feet from the edge of the Mesozoic red shale, and at a level of 617′ A. T., went down 325′, entirely in excellent ore and without reaching the trap.

In the Big Hill deposit, the ore-mass probably shallows up, for it is completely surrounded by trap; but the depth of ore still remaining beneath the terraces is unknown, although bore-hole No. 5 was once sunk to determine this point, without success.

This hole has already been alluded to as a supposed evidence of the basin-structure of the trap here.

The trap walls are so far off from the hole that if they came together at its bottom, their surfaces would only have a slope of about 16°; whereas the northern trap wall has a south slant of 38°, at a distance 700 feet further west, as shown by the line of bore-holes, Nos. 1, 2, and 3, and corresponding to the exposed face of trap in

* This bore-hole went down 2′ further into the trap and was then abandoned.

Big, Middle, and Grassy Hills, slanting between 30° and 40°. But calculation is set at naught by the excessive irregularity of the trap itself.

*Ore in Big Hill.*—From the Ore-Bank Company's railroad bridge crossing the pike, east of the weigh-house, to the eastern wall of trap rock, the ore-deposit is about 1400′ long and will average about 400′ in width.

The top level or terrace is 800′ A. T., and its area is about 700′ by 400′.

The south side is pretty generally worked down to an 800′ level, very irregular along the trap wall, owing to the shoulders which protrude out into the ore-mass.

The north side of this terrace consists almost entirely of the soft reddish-brown surface-ore 500′ by 200′ in area, and probably 50 feet thick. This ore is of course readily mined, owing to its soft character, much of it being dug with pick and shovel. Considerable black and brown mica and some hornblende are mixed with this ore here.

In the second level, just below the one described, tongues of trap are quite prevalent, especially near the north wall, dividing a 50-foot face of ore into four or five parts. These divisions, however, are by no means absolute, varying considerably in thickness and prominence. On the south side, the ore is rather lean, and contains large masses of the greenish soapy gangue-rock, mostly a double silicate of lime and magnesia. Mr. A. S. McCreath has kindly furnished me with the following analysis of this material (No. 1) which he calls "a greenish-white mineral associated with Cornwall ore," and in addition an analysis for comparison of No. 2, same material, found in Dillsburg ore.

| | 1. Cornwall. | 2. Dillsburg. |
|---|---|---|
| $SiO_2$, | 52.11 | 49.09 |
| FeO, | 10.74 | 5.78 |
| $Al_2O_3$, | 1.90 | 5.57 |
| CaO, | 12.54 | 22.65 |
| MgO, | 17.89 | 13.62 |
| $H_2O$, combined, | 2.03 | 1.30 |
| $CO_2$, | none | none. |

A third analysis (No. 3) of the limestone foot-wall and associated rock at Dillsburg is even more conclusive of the fact that the carbonates of lime and magnesia originally present in the gangue-rock have yielded to solution and left as a residue the greenish silicates of those bases.

*No. 3. Dillsburg Limestone.*

| | |
|---|---|
| $SiO_2$, | 14.70 |
| FeO, | 1.32 |
| $Al_2O_3$, | 2.99 |
| CaO, | 44.90 |
| MgO, | 3.57 |
| $H_2O$, combined, | .95 |
| $CO_2$, | 30.51 |

"To fully saturate all the CaO and MgO of the limestone and convert them into carbonate would required 39.20 per cent. carbonic acid. The $CO_2$ present falls far short of this—showing that part of the CaO and MgO must exist as silicates."

I do not doubt that analyses of the limestone and gangue-rock at the Reading, Fritztown, Boyertown, and other mines similarly situated along the southern border of the Great Valley, would show precisely similar results.*

The third level in Big Hill is at about 650′ A. T. The high slope rises from here 120′. The exposure of this immense face of ore is magnificent. Along the north side of the face the deposit is somewhat siliceous and shows some small trap prongs; but the general appearance of the whole slope is very favorable; the ore is very hard. Shipments from this level vary from 1000 to 1500 cars per month, and the work of the drill from 80′ to 150′ per day.

The fourth level is about 40′ below the last or at 605′ A. T. No active mining is pursued here at present. The wavy stratification of the ore- and lime-slate is well seen here. From this level to Furnace Creek is about 40′, all ore-ground, but preserved for railroad tracks, roads, etc.

*Ore in Middle Hill.*—The general appearance of the entire deposit in this hill is most excellent, and the company regard it as the great future supply-store, both from the increased width of the deposit here, and the testimony of the bore-holes, for the amount of ore beneath water-level.

Very little soft surface-ore remains here, being roughly confined to the 670′ contour-line on the map, and fast disappearing under the demand for it.

All this ore has the property of "roasting itself"; that is, eliminating a large percentage of its sulphur when exposed to atmospheric influences for about two years, through a vertical thickness of about 10 feet.

* See analysis of Warwick mine limestone, D 3, vol. ii., p. 322.

The characteristic features of the entire Cornwall deposit can be best studied on this hill, every variety of ore and gangue-rock being prominently exposed.

The deepest and least weathered ore is exposed in the water-level drift; but so far no appreciable increase in the percentage of iron pyrites has been met with here over the hard ore on the upper terraces; and this statement is equally true of samples taken from considerable depths beneath water surface in the bore-holes. The interstratification of ore and gangue-rock (a greenish-white, talcose, lime-magnesia slate) are well seen in this cut, in every visible particular resembling the appearance of the magnetic ore-deposits of this range as far east as Boyertown, Berks county.

About 300′ in the cut, there is a barren spot of bastard slaty limestone, in which there is probably a low percentage of iron (like analysis on page 892) in the form of a wedge or lenticular nodule of gangue separating the richer deposits of ore on either side of it.

Beyond this (further west) the face shows successive streaks of ore and limestone from 2 to 6 feet thick, suggesting the original richness and leanness of the pyritiferous lime-shales and a precise analogy to what I have seen at the Boyertown mines.

Milky quartz also occurred here in a lenticular-shaped pocket, 2 feet wide in the center and tapering down at the ends, and about 2 feet long, interbedded entirely in ore.

A most curious quartz conglomerate, containing pebbles of white and pink quartz from the size of a pea to that of a large marble, accompanied with feldspar and having a greenish cast, occurs between the 650′ and 670′ contours, and according to the superintendent, in masses weighing from a ton down to 5 cwt. and smaller sizes, but always surrounded by ore, and without any definite arrangement. This will be referred to later in this paper.

*Copper in Middle Hill.*—On both sides of the hill, along the limestone ridge and knobs shown on the map, numerous small drifts mark the former explorations for copper. This metal has been found in the native state, as carbonate and red oxide, but chiefly as sulphide. Its occurrence is marked by great irregularity and in thin veins, which, traced downwards, always change into the double sulphide of copper and iron, and in time into iron pyrites entirely.

This change usually takes place in a vertical distance of 30 to 40 feet.

*Ore in Grassy Hill.*—On Grassy Hill, owing to the cessation of

active mining operations until the advent of the Water-Level Cut this far west, very little of interest can be seen.

No break in the southwestward extension of the ore-deposit from Middle Hill across the branch of Furnace Creek, is apparent.

The general appearance of the ore-mass is uninviting now, owing to the presence of much wash-material and a large mass of decomposed slaty limestone-clay, which covers more than one-half the area of the present excavation, extending from the railroad track south to the red-sand wash. A considerable amount of red hematite was mined from this part of the hill, while to the north and west, adjacent to the trap wall, the greenish-black magnetic ore, slate, and shoulders of trap—such common features elsewhere,—are repeated in this hill. The ore has been mined for about 70 feet from the top of the hill.

No bore-holes have been drilled here; and the idea that the ore deposit shelves up southwestward here, as it does northeastward in Big Hill, has no foundation in fact; and the only reason that can be assigned for it is that the *west* trap wall slants *eastward* in a steep and irregular manner.

*The Stratification of the Ore-Deposit.*—The second most striking feature to the eye of the observer standing in the valley of Furnace Creek, is the universal, regular, and *apparently* horizontal stratification of the whole deposit, exhibited along the faces of the stopes.

It is evident that this stratification is original to the formation, and antedates its conversion into ore, or at least antedates the development of its present characteristic mineralogical features; for the whole mass consists of thick and thin beds, deposited one upon another as in the case of unchanged sedimentary strata, in a practically horizontal order.

But when this stratification is viewed sideways, in the side stopes, and especially in the great Water-Level Cut through Middle Hill, a general dip of the ore-beds towards the southwest, in almost all parts of the mine, is plainly discerned. This southwest dip, from Big Hill on the east through Middle Hill to Grassy Hill on the west, amounts to about 5°—sometimes less, sometimes as high as 10°.

Wherever possible, drilling operations are directed against the horizontal basset-edges of the beds; by this method, heavier and cleaner blasts are secured.

Along the south side of Middle Hill, where the limestone beds (to be described immediately) appear, there is some departure from the general direction and strength of dip, which can be perhaps accounted for by a general settling of the whole ore-formation during

the process of change from its original condition of sedimentary lime-shale beds, to its present state of a stratified ore-mass; to which change of character and position the undissolved limestone beds would only partially conform.

The situation of the ore-mass in the great limestone valley and surrounded on three sides by a formation of lime-shales (to be described further on) would render it probable that it was originally a formation of lime-shales containing more or less magnesia, silica, alumina, and iron pyrites. This probability is increased by the laminated stratification, and is made fairly certain by the fact that a considerable thickness of unchanged lime-shale layers, passing upward into solid beds of hard limestone, blue, white, and semi-crystalline, is exposed along the southern side of Middle Hill, in the body of the ore-mass, which has been mined on both sides of them, beneath and above them. These unchanged lime-shale beds are seen at one place resting upon the ore; and at another place the limestone beds dip under the ore-layers at the same angle, changing gradually, both longitudinally and vertically, into ore.

In addition to these facts, there occurs on the 650′ terrace the remarkable exposure of sandstone and conglomerate already referred to, which must be regarded as interstratified with the ore-mass. This rock extends through a range of 10 feet of the ore vertically, 100 feet long and 20 feet wide. But so far it has not been met with elsewhere in the mine. It must be a part of the original stratification of the ore-mass, for fully 50 feet of ore have been quarried from its surface. Two of these blocks still stick up out of the wide terrace, awaiting the westward advance of mining development to dislodge them. They could get into the ore-deposit in no known way, and no rocks in the neighborhood bear any resemblance to them.

If, as has been suggested by Professor Lesley, a resemblance can be established between these rocks and similar isolated masses found in some of the large brown-hematite mines of the State,* it would be so much in evidence, that, however formed at first, "the Cornwall magnetic iron-ore mass is as sedimentary a formation as the brown hematite ore-masses in other parts of the State, and that it was like them, a formation of magnesian limestone beds, some thick and hard, others very thin, laminated, soft, and easily acted upon by water." Professor Lesley moreover remarks, that the magnetic quality of the

* Professor Lesley refers particularly to the Penna. Furnace Bank in Centre county, Pa. Annual Report 1885, Penna. Geol. Survey.

Cornwall ore does not invalidate such a conclusion; for Dr. Genth found minute crystals of magnetic iron-ore in the limonites of Centre county.* He also found that some of the limonites had parted with a portion of their water of hydration. Both of these facts indicate the beginnings of a change of the brown hematite ore-bodies from their condition of hydrated peroxide (limonite) towards that condition of anhydrous sesquioxide (magnetite) to which we find the whole body of the Cornwall ore to have been already brought.

*Interstratification of Limestone Beds.*—Beds of bluish-white limestone, some of them a fair white marble, crop at several places in the mine, in knobs and ridges, in such a way as to show that they are regularly interstratified with the ore-mass, left in an unchanged condition, while the ore has been mined away around them. And this is one of the strongest proofs of the original stratification of the whole deposit.

In texture and color they resemble the limestone of the Lebanon Valley quarries, and the thin lime-shale beds in the railroad cuts north of Cornwall. They must belong to the great limestone formation No. II. of the valley, or to the transition layers between the Siluro-Cambrian limestone and the overlying Hudson River slates, No. III.

The southern range of limestone in Middle Hill is about 1000′ long, extending in a ridge from the summit south of the Water Level Cut westward to the ore-cut running south from bore-hole No. 4. The ridge is pierced near its east end by the Cornwall Ore-Bank Company railroad (see map) in a cut 20′ deep.

In this cut the solid beds of white dolomitic marble are seen alternating with shaly limestone, without any traces of iron pyrites, capped with some remains of the ore which probably once covered them, and all dipping northwestward 30° into the great body of the ore.

This locality becomes of special importance; for Mr. Boyd, the superintendent, informs me that an old drift (in pursuit of copper-ore) was once driven in on the *north* side of the ridge, 40′ *below the terrace*, which was, of course, expected to strike the limestone beds; instead of which the drift, commenced in ore, continued in iron-ore under the limestone; showing that the limestone beds lose themselves downwards and gradually turn into ore.

The strike of the limestone beds should bring them out into the water plain 45′ below.

* See Report T 4 of Penna. Geol. Survey.

About 1200′ from the little cut, however, white limestone is exposed in Big Hill, about 40′ above the creek, just north of the carpenter-shop, where the south wall of trap ends. It seems a little too far north to be referred to the strike of the Middle Hill beds; it is partly concealed by ore-piles, so that its dip is obscure, but seems to be to the southeast.

The section of northwest dipping limestones in the cut reads:

| | | |
|---|---|---|
| 1. | Ore, lying on the sloping northwest walls of limestone. | |
| 2. | Limestone beds, dolomitic, blue, and crystalline, . . | 10′ to 15′. |
| 3. | Limestone, shaly and greenish shale, . . . . . | 12′. |
| 4. | Limestone, solid, blue, . . . . . | 8′ to 10′. |
| 5. | Limestone, slaty and with a reddish-brown color, . . | 6′. |
| 6. | Limestone (at the base), massive, in two beds, white in color and crystalline, . . . . . | 15′ to 20′. |

There is some slight curvature and crumpling in the beds, but they generally dip northwest 30°. This dip is transverse to the southwest stratification of the ore mass of the hill taken as a whole. But it is no evidence of non-conformity; for in the continuation of this ridge southwest, white crystalline limestone and lime-shale beds are exposed for 600 feet, with the same northwest dip, and include three distinct ore-horizons regularly interstratified with the lime beds, showing plainly that the ore was originally lime-shale; and then over these comes the principal ore-mass, stratified in the same manner and still dipping in the same direction. All this is repeated in the cut 800′ southwest.

Here a ridge of limestone and lime-shales rises to a peak at its west end, about 60 feet above the great terrace. At its east end lime-shale beds are exposed, above, beneath, and on each side of which ore has been mined.

The long narrow ridge has been left standing like a wall between the great ore-floor north of it and a deep wide trench of ore-ground south of it.

The south side of the ridge shows alternate lime-shales and stratified ore, descending westward at about 10° beneath the massive white limestones marking the western peak, where there is a sharp contortion of the crystalline beds and, possibly, a reversal of the dip towards the south.

Here is exhibited the feature of crumpled beds between uncrumpled beds, showing great lateral pressure, which would happen in alternate beds of resisting and yielding limestone and shale, the whole mass settling down upon itself as it changed its bulk, during the process of change into ore.

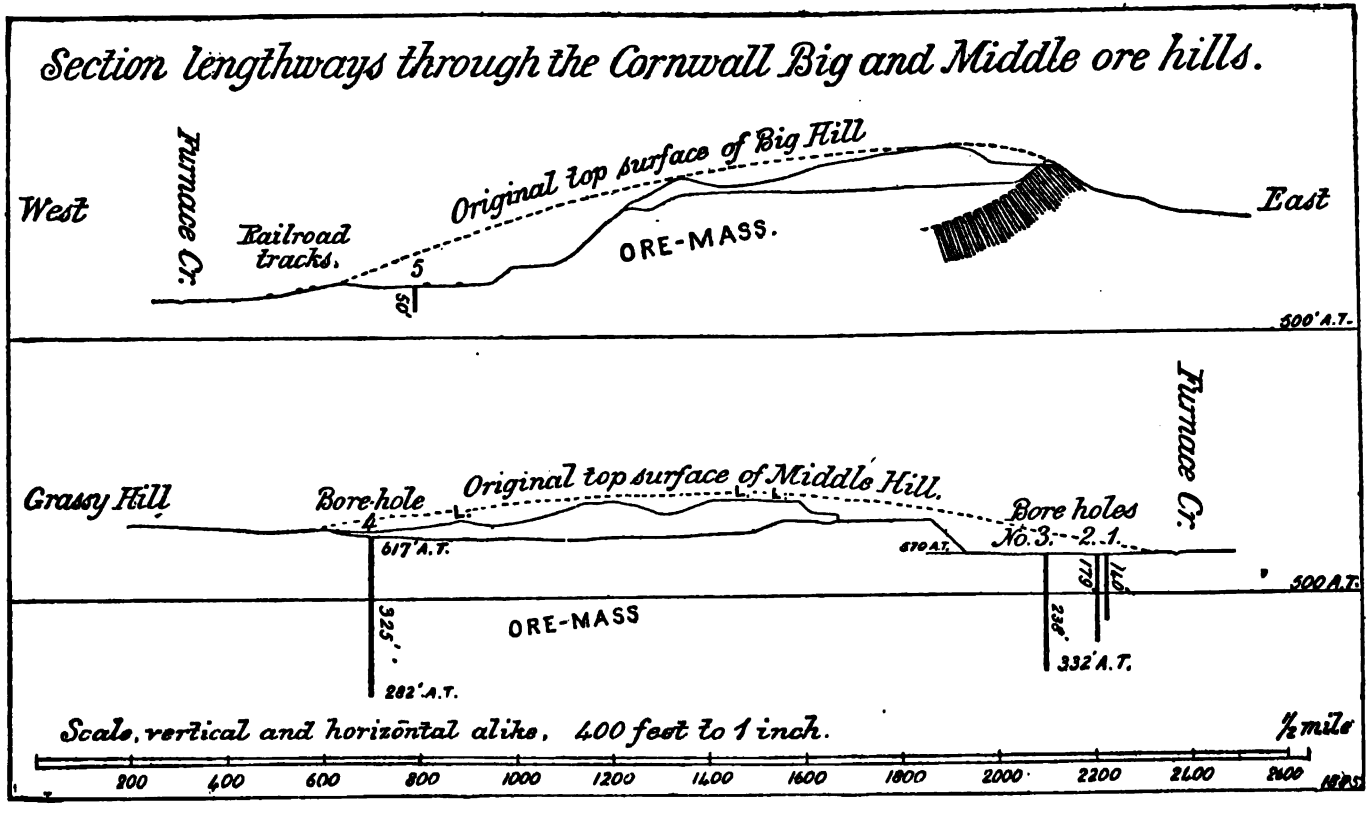

Section lengthways through the Cornwall Big and Middle ore hills.
West
Furnace Cr.
Railroad tracks.
Original top surface of Big Hill
East
ORE-MASS.
5
50
500' A.T.
Furnace Cr.
Grassy Hill
Bore-hole 4
Original top surface of Middle Hill.
Bore holes No. 3. 2. 1.
617' A.T.
610 A.T.
500 A.T.
ORE-MASS
325'
282' A.T.
238'
332' A.T.
Scale, vertical and horizontal alike, 400 feet to 1 inch.
½ mile
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 FEET

FIG. 4.

The limestones exposed on the north side of Middle Hill, in two little peaks, are equally isolated. These two peaks contain different limestones, one above the other, with ore between the two, between them and the trap, and, of course, above them to the south. The dip here is evidently towards the south. But these beds can not be traced vertically or longitudinally in the hill; they show nowhere in the slopes to the east, and cannot be found west of their present position, changing in all directions into ore.

Fig. 3 shows the relation of these peaks to the stopes, to each other, and to the tongues of trap already mentioned. Southwest of these peaks there is another isolated outcrop of hard white limestone exposed in a low cut at the end of the railroad track. The rock is much broken and no certain dip can be assigned to it, though it is probably to the south. It is in the midst of the ore mass and, from its position, evidently above the limestone in the peaks.

Another exhibition of limestone occurs still further west at the railroad switch in Grassy Hill. The dip is here southwest, and apparently has no relation to the other exposures described.

Returning to Middle Hill, the limestone beds of the knob nearest the trap tongues on the north side are slightly warped, dipping south-southwest, and are 15′ to 20′ thick, carrying in the top, stratified ore-layers, with some talcose magnesian slate, in all 25′ thick. The limestone is very much altered and charged with copper.

In both peaks the limestone is barren of ore, but porous, pock-marked and honeycombed. Some Cornwall lean ore lies near by in exactly the same honeycombed condition and partially changed to pipe-ore, which a blowpipe determination showed to be a manganiferous limonite (brown hematite).

All this is further evidence that even the solid limestone beds of the formation have been partially subjected to the same process which has converted its original lime-shales into the stratified ore-mass of the mines. The place of the different solid limestones in the stratified series cannot be made out; and they cannot be used as keys to the structure from their isolated position. And the notion of an ore-basin founded on their dips must be abandoned.

As much as 35′ of solid ore is visible in the south face of the trench back of the limestone ridge on the south side of Middle Hill, standing against the Mesozoic red sand wash; and it cannot be said, in the absence of bore-holes or developments, how far south it extends

or what is the nature of the unrevealed ground bordering the junction of the Mesozoic formation to the south.

A longitudinal section through Big and Middle Hill, given in Fig. 4, shows the true southwestward slope of the deposit towards Grassy Hill. There was no original basin. The trap has cut diagonally through the southwest-sloping ore-formation. This is the reason why the limestone beds of the two peaks seem to be near to the bottom of the ore-mass, because they come so near the trap; whereas they actually lie very high in the series, having 400 or 500 feet of ore under them.

The trap dyke has cut its way through all this ore-mass to get within 20 feet of the limestone peaks.

The northeastward rise of the whole stratification has carried the limestone and accompanying measures into the air; and this is the reason why the limestone beds have not been cut in the stopes and terraces east. For the same reason, the ore at Grassy Hill is much higher than that in Big and Middle Hills. The extension of the ore to the west-southwest is thus provided for; but to the south-southeast I regard the field as still open to conjecture.

The wash from the red sandstone and shale hills to the south, has brought down great quantities of gravel, sand and clay to the present border line of the mine-quarries, and it cannot be known how much, if any, ore it covers up.

However, in the valley of Furnace Creek, where the running water has carried away a good deal of this wash, it is made fairly probable that the ore extends at least 400′ south of its formerly ascribed limits, coincident with the development in Big and Middle Hills, as shown on the map accompanying this paper.

Ore was raised here in making grade for the railroad track recently, which, at least, extended the spread of the deposit much further south than it was previously admitted to extend.

## III. The Mesozoic Red Sandstone and Shale Formation at Cornwall.

Immediately south of the south trap wall at Big Hill, a series of exposures of Mesozoic, altered, purple-colored, clay strata occurs, having a slaty texture, and filled with decomposed whitish grains of feldspar, well seen along the Cornwall Ore-Bank Railroad cuts, from the carpenter-shop to the engine-house, a distance of 1000 feet. No positive dip can be assigned to these metamorphosed rocks; but it is probably to the northwest.

But at the end of C. & L. R.R. siding, 350′ southeast of the engine house, there is a small, but clean, exposure of Mesozoic measures, unquestionably dipping to the northwest at an angle of about 18° and exposing the following beds:

| | |
|---|---|
| Soil and subsoil, full of red and white quartz pebbles, . . | 8′ to 10′. |
| Red shale and sandstone layers, somewhat broken, . . | 1′ or more. |
| A bed of gray conglomerate; without distinct stratification and holding quartz pebbles and some feldspar, . . . | 5′. |

Along the Cornwall and Mt. Hope Railroad, further southeast about 1000′, a small bed of sandstone, very much disintegrated, is exposed in a railroad cut, apparently dipping 15° north 10° east, the exposure being about 6′ thick, under which lie broken shales 8′ thick and then a loose pebble-rock 3′ to 4′ thick. In two long cuts further south towards the summit of the Dividing Ridge, red sandstone and shale occurs dipping northwest, accompanied by pebble-rock.

Along the Mt. Hope public road, southwest from Grassy Hill, the measures, greatly jointed, likewise seem to dip northwest, so there can be but little doubt that the inclination of the Mesozoic formation, as a whole, is *generally* towards the northwest, in obedience to observation all along the range to the east and west.

The exposures at Cornwall, however, are very few and greatly concealed by the gravel drift from the Dividing Ridge. East-southeast of Big Hill two prominent ridges, Sheep Hill and Templeman's Hill, are made by an outcropping series of Mesozoic altered sand and mud strata, with a gray color and distinctly laminated, which are said to take a high polish. In the one small exposure seen on the north slope of Sheep Hill near the summit, the dip was obscure, though possibly *southeast*. At the north base of this hill and the east base of Big Hill, is the old *Elizabeth Mine*, now abandoned, showing a cut about 20′ deep and 200′ long, with trap on the west side, from which a considerable amount of Cornwall magnetic ore was formerly mined.

Nothing is known of the depth of the deposit here; but the locality serves, in conjunction with the Donner opening further east (beyond the limits of the map), to mark the extension east of this ore-range, just as the finding of the same ore in the Carper Bank, 5 or 6 miles west of Cornwall, marks its western prolongation.

It has been already stated that the north slope of the Dividing Ridge and subordinate hills is covered with a mantle of wash or red sand-gravel, with red and white quartz pebbles. The thickness of

the wash varies greatly; in some places only 10′, in others, 100′ thick.

And this is practically all that is known of the Mesozoic formation in the vicinity of Cornwall, except the record of a bore-hole started in the fall of 1885, by Mr. C. B. Grubb, of Lancaster, on an isolated ridge north of the main ridge, about 3200 feet due south of Middle Hill, and at about 975 feet above tide.

The record of this hole received, showed that the drill went through 125′ of red sand and gravel wash before meeting solid rock-strata. The report at 250′ was a passage through red sandstone, gravel and mottled red shale. This character of rock continued down to 700 feet below the surface, where the drill entered, according to Mr. Grubb, a "white conglomerate and blue strata, with considerable iron, copper and sulphur mixed" and continued in this formation.

## IV. The Chemical Constitution of the Cornwall Ore.

The first complete analysis of Cornwall ore made by Mr. A. S. McCreath for the Geological Survey of Pennsylvania, shows its chemical constitution well, but hardly its percentage of iron, unless taken with his later analyses of samples gathered by himself, in August, 1881. This first analysis, No. 1, is *Cornwall "white ore,"* from the east face of Middle Hill:

| | | |
|---|---|---|
| Bisulphide of iron, | 3.431 | per cent. |
| Peroxide of iron, Sesquioxide of iron, | 51.852 | " |
| Protoxide of manganese, | .371 | " |
| Oxide of cobalt, | .490 | " |
| Sulphide of copper, | 1.472 | " |
| Alumina, | 2.969 | " |
| Lime, | 9.510 | " |
| Magnesia, | 7.917 | " |
| Sulphuric acid, | .534 | " |
| Phosphoric acid, | .038 | " |
| Carbonic acid, | none | |
| Water, | 1.120 | " |
| Alkalies, etc., undetermined, | .... | |
| Silica, | 19.750 | " |
| | 99.454 | " |
| Metallic iron, | 39.600 | " |
| Metallic manganese, | .288 | " |
| Metallic copper, | .507 | " |
| Sulphur, | 2.557 | " |
| Phosphorus, | .017 | " |
| Phosphorus in 100 parts of iron, | .042 | " |

At the office of the company at the mines six blocks of ore, each intended to be a cubic foot in dimension, have been dressed and placed in two columns of three each on each side of the Superintendent's office door. These blocks were designed to show each grade of ore occurring in the mines, and after being dressed and weighed, borings were taken from them for analysis. The following table shows their weight and percentage:

| | | | | | |
|---|---|---|---|---|---|
| First | block, weighing | 224 pounds, | 1st grade, | 62 per cent. iron. | |
| Second | " " | 257 " | 2d grade, | 57 " | " |
| Third | " " | 257 " | | 55 " | " |
| Fourth | " " | 228 " | 3d grade,* | 44 " | " |
| Fifth | " " | 231 " | | 42 " | " |
| Sixth | " " | 199 " | 4th grade, | 24 " | " |

Under this arrangement of grading—which is purely a chemical and *not* a commercial one—Mr. McCreath's analysis of No. 1 sample first given would fall under the head of the third grade, nearly.

The following analyses of Mr. McCreath are arranged in the order of their percentages of metallic iron, to show the chemical constitution of the different grades of ore.†

| | No. 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|
| Metallic iron, | 64.900 | 57.050 | 51.450 | 51.050 | 48.800 | 46.400 | 41.900 |
| " manganese, | .158 | .064 | .072 | .115 | .057 | .238 | .194 |
| " copper, | .005 | .447 | .559 | .295 | .599 | .066 | .319 |
| Alumina, | .324 | 1.394 | 1.080 | 1.289 | 2.315 | 7.815 | 4.970 |
| Lime, | 1.010 | 2.740 | 2.600 | 2.340 | 4.330 | 2.550 | 2.810 |
| Magnesia, | 1.131 | 3.942 | 6.652 | 6.616 | 5.531 | 2.738 | 7.459 |
| Sulphur, | .071 | 2.531 | 2.459 | 3.271 | 1.807 | .050 | .428 |
| Phosphorus, | .014 | .007 | .010 | .010 | .018 | .023 | .019 |
| Silica, | 3.980 | 8.650 | 12.270 | 11.560 | 12.940 | 18.040 | 20.910 |
| Phosp. in 100 parts of iron, | .021 | .012 | .019 | .019 | .036 | .049 | .045 |

No. 2.—Sample of 115 pieces of "Nigger-head ore," from Middle Hill.

No. 3.—Sample of "No. 3 ore," from east face of Middle Hill.

No. 4.—Sample of fine or soft ore, "No. 3 ore," from west cut, north side of Middle Hill.

No. 5.—Sample of fine or soft "No. 3 ore," from west cut, south side of Middle Hill.

No. 6.—Sample of "No. 1 ore," east face of Middle Hill.

No. 7.—Sample of Fix or Wash-ore, from near engine-house, south side of Big Hill.

No. 8.—Sample of No. 1 light ore, from west cut, south side of Middle Hill.

All samples previous to analysis were dried at 212° F.

---

* It was intended that these blocks should be exactly one cubic foot, but it was impossible to get perfectly homogeneous cubes. This accounts for the 44 per cent. block weighing less than the 42 per cent. block.

† For this suggestive arrangement I am indebted to Professor Lesley, of the Geological Survey.

A comparison of these analyses establishes the important fact that the richness of the ore depends upon the percentage of silica in combination with its three bases, alumina, lime, and magnesia, not in equal quantities, but in varying proportions of the three. This will be made clearer, perhaps, by the following summary, which deals only in round numbers:

| | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (1) |
|---|---|---|---|---|---|---|---|---|
| Iron, . . . | 65 | 57 | 51½ | 51 | 49 | 46½ | 42 | 39½ |
| Silica, . . . | 4 | 8½ | 12½ | 11½ | 13 | 18 | 21 | 20 |
| Alumina, Lime, Magnesia, . . | 2½ | 8 | 10½ | 10½ | 12 | 13 | 15½ | 20½ |

This is additional proof of the existence of insoluble silicates in the Cornwall gangue-rock before referred to. It is also additional evidence of stratification,* "the silicates being in the form of a feldspar mud, charged in places with fine quartz sand; the rest of the lime and magnesia being carried off as carbonates in solution by carbonic acid waters; potash and soda being entirely absent; and phosphorus in no case reaching *three hundredths of one per cent.*"

Sulphur is an important, constant, but very variable constituent of the Cornwall ore, although so generally distributed through the ore-mass that the average amount of it in any one ton must be very nearly equal for all parts of the deposit (except, of course, in the weathered surface-ore, exposed for a long time to the leaching of atmospheric waters.)

This fine surface-ore is the commercial "No. 1 ore" of the Cornwall Ore Bank Company's grading, yielding 50 to 55 per cent. iron, and being only used to a limited extent as a mixture for fixing puddling-furnaces, etc. The "run of mine," No. 2 ore, mostly a fine or small lump ore, carries from 42 to 50 per cent. of iron, and from 2.5 to 3 per cent. of sulphur. The "select ore," No. 3, forms the largest part of the output; is mostly lump-ore, with about 48 per cent. iron and the same amount of sulphur as the No. 2.

No. 1 is not roasted, but it is only a small part of the general output. All No. 2 and No. 3 ores are roasted. The following analyses of *roasted Cornwall ore*, made in April, 1880, were furnished by Arthur Brock, Esq., of the North Lebanon Furnaces:

---

* See Annual Report for 1885, Geological Survey of Pennsylvania, J. P. Lesley.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Iron, | 57.85 | 56.78 | 55.90 | 55.43 | 55.35 | 54.32 |
| Silica, | 9.50 | 10.70 | 11.85 | 11.63 | 11.00 | 11.30 |
| Alumina, | 3.65 | 4.50 | 3.80 | 3.24 | 4.21 | 3.70 |
| Lime, | 2.12 | 2.40 | 2.30 | 2.06 | 2.32 | 2.73 |
| Magnesia, | 3.76 | 4.13 | 3.52 | 3.47 | 4.00 | 4.31 |
| Sulphur,* | .45 | .40 | [.97] | [.42] | .50 | [.85] |

If the silicate bases are taken together, we have:

| | | | | | | |
|---|---|---|---|---|---|---|
| Alumina, Lime, Magnesia, | 9.53 | 11.03 | 9.62 | 8.77 | 10.53 | 10.74 |

Additional light is cast upon the chemical constitution of the Cornwall ore by comparing its analyses with the following analyses of similar magnetic ores from the Boyertown, Reading, and Wheatfield mines in Berks county, and Dillsburg mines of York county, all, but No. 3 perhaps, situated similarly near the edge of the Mesozoic country, and geologically connected with the underlying older rocks. These analyses are arranged (to the nearest second decimal) as before, according to their iron percentages, and are as follows:†

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Iron, | 43.40 | 43.00 | 42.75 | 39.60 | 38.05 | 34.55 |
| Silica, | 11.13 | 14.02 | 22.10 | 20.20 | 16.13 | 21.21 |
| Al. & L. & Mg., | 18.90 | 13.86 | 11.45 | 19.18 | 19.77 | 22.38 |
| Copper, | .01 | .59 | | .12 | .56 | .17 |
| Manganese, | .01 | | | .23 | .42 | .21 |
| Sulphur, | .43 | .53 | .59 | 1.94 | 1.14 | 1.64 |
| Phosphorus, | .09 | .02 | .01 | .06 | .04 | .03 |

No. 1.—"Black Ore bed," 163 pieces, Warwick mine, Boyertown, A. S. McCreath.
No. 2.—Island mine, Reading, Slope No. 1, Leonard Pickitt.
No. 3.—Dillsburg ore, Underwood mine, A. S. McCreath.
No. 4.—Wheatfield mine, Berks county, Leonard Pickitt.
No. 5.—Island mine, 25 lbs. A. S. McCreath.
No. — "Blue Ore bed," Phœnix mine, Boyertown, 20 lbs. A. S. McCreath.

If the Cornwall deposit shows any distinctive characteristic when compared with the others, it is in its larger percentage of sulphur, while it shares with the Wheatfield deposit a prominence in its copper constituent.

The Cornwall ore has been found very well adapted as a neutralizer for most of the hematites of the Great Valley and the fossil ores of Central Pennsylvania, when roasted to one per cent. or less

* Those in brackets [ ] are sulphuric acid.

† Complete analyses of Nos. 1, 2, and 4 will be found in Report D 3, vol. ii., of Pennsylvania Survey, as well as the partial analyses of Nos. 5 and 6. No. 3 is found in Report MM.

of sulphur. The magnesia in the ore makes good company for most of the dry limonites of the valley, working a hot cinder, and cleaning, without scouring the crucible and fore-hearth.

Associated always with a greenish slate, mainly the silicates of lime and magnesia, the color of the ore is not the intense black of the magnetites of the New York and New Jersey Azoic rocks, to which it bears but a very slight physical relation.

*Magnetic Quality of the Cornwall Ore.*—It may be safely concluded, that the Cornwall ore deposit has experienced three stages of development; being originally a formation of (pyritiferous) lime-shales; then a great brown hematite formation; and finally a magnetic ore deposit; always retaining its original place and general stratification, but becoming consolidated by the loss of *most* of its lime and magnesia, all of its water of crystallization and part of its oxygen, and greatly reduced in bulk, without the loss of its original grains of sand (such as are very visible in the brown hematite ores) and with a concentration of its percentage of iron.

What the original percentage of iron was, is open to conjecture. In some brown hematite mines the beds change to carbonate of iron below drainage-level; in others, especially the pipe ores of the Nittany Valley in Central Pennsylvania, I have seen cores of sulphuret of iron left unchanged in the centre of the limonite masses. It is, however, difficult to ascribe the production of the Cornwall magnetic ore-mass to the dissolving action of cool running water on the lime-shales, which is all that is required to produce the brown hematite deposits.

But at Cornwall, Wheatfield, Reading, Boyertown and Dillsburg, the five chief localities in Pennsylvania where this character of ore has been found, trap dykes are always present in the general border range of the Mesozoic formation. It is quite possible therefore to account for the magnetic stage of development in these ores by the resulting action of heat, either directly through the lava of the trap dykes or indirectly by the agency of boiling spring waters.

## V. The "Cornwall Slates."

I have given this name to an area of lime-slates along the north border of the Mesozoic red shale, about 4 miles long and ¾ mile wide at Cornwall and tapering to a point east and west. The shape and position of this slate area is shown on Fig. 1, between dotted lines.

They hold important relations to the ore-deposit, and their age and order in the Palæozoic system has been much debated; it is even yet a matter for positive proof whether they overlie or underlie the valley limestone, though personally I lean strongly to the former view.*

The cross-section, Fig. 5, has been constructed from exposures along the Cornwall R. R. from Lebanon to Cornwall, independent of any theory, and seems to make my conclusion fairly correct.

The one or two rolls in the limestone cuts of the Lebanon–Cornwall Railroads, do not look like great anticlinal arches; and there is no appearance of overturned dips in the general flat plain of the valley. Consequently the Cornwall slates may be reasonably supposed to be occupying their original position, *overlying* the limestones, and dipping gently southward, everywhere south of the Mill Ridge, which runs northeast and southwest, and just south of Cornwall Station.

If this be so, it necessarily follows that the *Cornwall Slates* are the same as those existing through the middle of the Great Valley, north of Lebanon and Harrisburg, and which are exposed in all the bends of Conedoguinet Creek in Cumberland county, where they make a transition formation between No. II. (limestone) and No. III. (slate) consisting of alternate beds of lime-shales and limestones.

At Cornwall, these lime-shales are much altered either by pressure or heat; but they can only be well seen in the railroad cuts and in small exposures in the gaps through Mill Ridge.

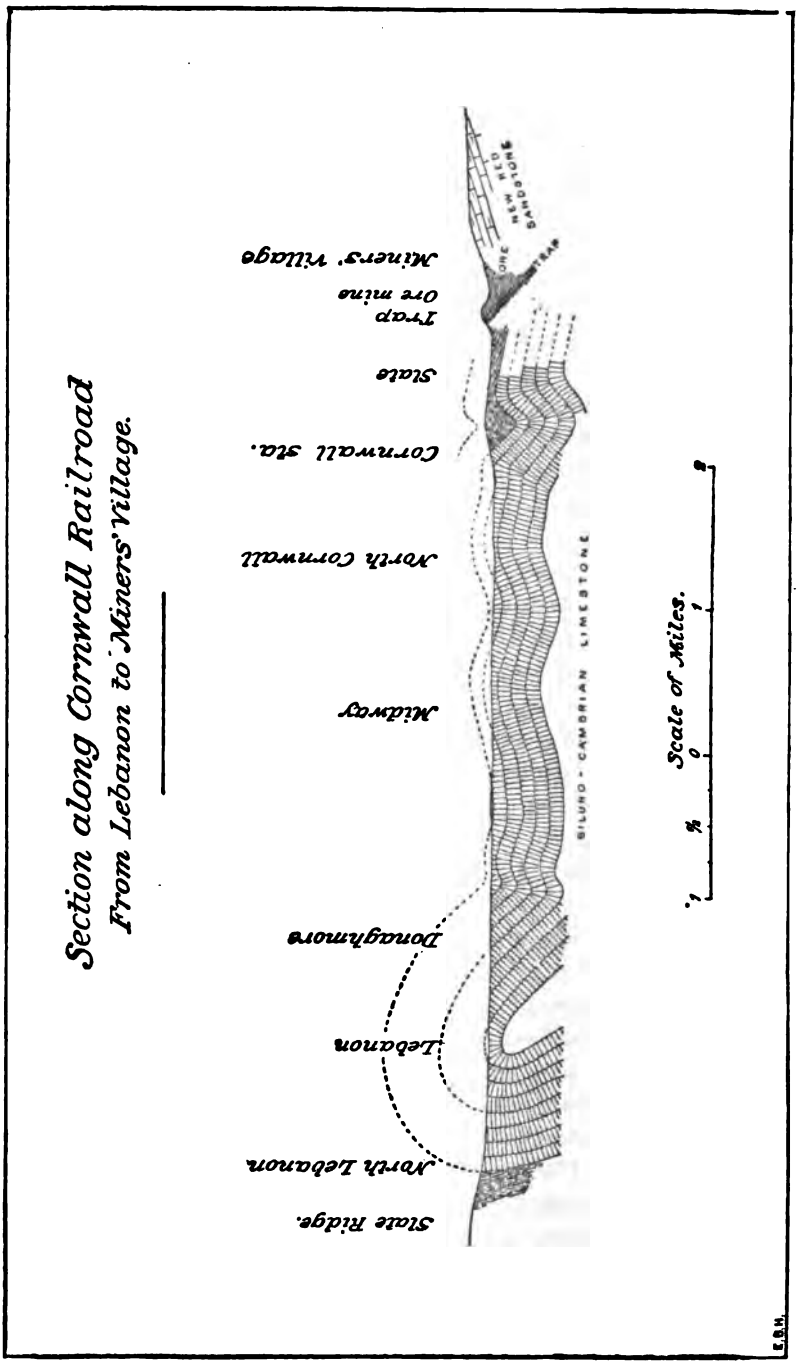
This ridge is fully ½ a mile north of the north wall of trap at the mines, and all that is known of the intervening valley is that it has throughout a broken slate surface-soil, mixed with pieces of trap and "nigger-head ore" and generally covered with a wash from the streams passing through it.

Both the apparent synclinal structure of Mill Ridge and the fact that its slates are hard enough to make a persistent ridge for several miles in length, would intimate that the valley south is occupied by an anticlinal of limestone; but no exposures could be found, and no information could be got from property-owners to decide the question, which is manifestly an important one. That the ridge is a synclinal seems evident, and being only 3 or 4 miles long, it would naturally have an east and west end by erosion.

---

* Prof. H. D. Rogers identified these "Cornwall Slates" with his *Upper Primal Series*, belonging to Formation No. I. overlying the Potsdam (Primal) Sandstone.

FIG. 5.


Section along Cornwall Railroad
From Lebanon to Miners' Village.
State Ridge.
North Lebanon
Lebanon
Donaghmore
Midway
North Cornwall
Cornwall Sta.
State
Trap
Ore mine
Miners' village
NEW RED SANDSTONE
TRAP
SILURO - CAMBRIAN LIMESTONE
Scale of Miles.
E.B.M.

The crumpling of the slates in the railroad cut can be so explained; and the fault which is so beautifully shown in the west wall of the cut, is merely one of the crumples broken, as is plainly proved by the insignificance of the break in the east wall. The slates here are very rough in appearance, brown in color and with streaks of quartz. The cleavage planes are obscure, one set seeming to be steep to the northeast.

Other proofs of the superposition of the slates over the valley limestone might be furnished by reviewing the geology of the country east and west of Cornwall; but this does not seem necessary here.

## VI. The Mining of the Cornwall Ore.

Until within recent years the mining of iron-ore at Cornwall was carried on under the present system of quarrying stone or loose rock. Each individual shareholder in the ore-bank raised ore from his own "mine hole," loading at first directly into wagons that were driven into the banks on the top of the hill; and when that method was superseded by the advent of a railroad in 1853, tracks were laid upon which the cars were switched to the various "holes." This systemless method of mining, which allowed no means for determining the amount of ore taken by any one individual owner, led to repeated trouble and litigation.

Many interesting facts were elicited from the testimony of witnesses in the law-suits which followed, relating to the methods and costs of mining and the character of ore, all of which are now a matter of court record.

A. Wilhelm, in charge at that time of the interests of R. and W. Coleman, two of the owners, testified that the average cost of mining between the years 1851–1859, including mining, powder, master miner's salary and loading on wagons or cars, was $16\frac{28}{100}$ *cents per ton.*

Chas. B. Forney, the manager of the G. D. Coleman or North Lebanon Furnaces, testified to making a ton of iron from 2.23 tons of ore and 2.55 tons of coal (anthracite). In 14 years, from 1845–1859, the average ore per ton of iron was 2.14 tons; coal 2.47 tons and limestone 1400 pounds. Cost total $11.17.

J. Taylor Boyd, then Superintendent of the R. & G. D. Coleman interests, now General Superintendent of the Cornwall Ore-Bank Company, and to whom much of the credit of this paper is due, put the average cost of mining their portion of the hill between 1853–

1859 at 30.62 cents per ton, including all expenses connected with mining, superintendence, making sales, etc., but *exclusive* of commissions. The lowest cost per ton was 22 cents. But the *actual cost of mining alone* between 1852–1859 (see table 2) varied between 11.04 and 22 cents.

In 1852 mining proper began at Cornwall and the first sale of ore was made. Four years before, in 1848, there were seven charcoal-furnaces within a radius of twenty miles of Cornwall, each averaging 1000–1200 tons of pig iron a year.

Extracts from two tables are presented below, which sharply reflect the condition of the iron industry at Cornwall at this period, and while they are only partly germane, seem nevertheless to need no apology for their introduction, on account of their historical interest. Both are taken from the court records and were compiled (No. 1) by C. B. Forney, Esq., and (No. 2) by J. Taylor Boyd, Esq.

The first table is based upon materials delivered to the North Lebanon Furnaces, on the Union Canal, north of Lebanon.

TABLE I.—*Pig-iron at North Lebanon Furnaces between the years* 1848–1858.

| Year. | Cost of iron at furnace. | Net price of iron at furnace. | Iron made. | | Cost of ore. |
|---|---|---|---|---|---|
| | | | Tons. | Cwt. | |
| 1848 | $13 63 | $19 46 | 7132 | 04 | $1 11 |
| 1849 | 14 14 | 18 11 | 6847 | 13 | 1 51 |
| 1850 | 16 93 | 15 76½ | 4450 | 11 | 2 31 |
| 1851 | 19 32 | 16 46 | 4501 | 17 | 1 86 |
| 1852 | 23 00 | 16 80 | 2199 | 11 | 1 83½ |
| 1853 | 15 60 | 26 27 | 6467 | 04 | 1 73 |
| 1854 | 17 76 | 27 34 | 7837 | 06 | 1 82 |
| 1855 | 30 61 | 19 41 | 1835 | 15 | 1 85 |
| 1856 | 16 17 | 20 77 | 7157 | 00 | 1 41 |
| 1857 | 22 33 | 21 48 | 4129 | 10 | 1 25 |
| 1858 | 16 59 | 14 24 | 5066 | 00 | 1 30 |
| Average, | $18 73 | $19 62 | 5238 | 10 | $1 63 |

TABLE II.—*Cost of Mining Ore at Cornwall Ore Mines, etc.*

| Year. | Average price sold per ton at the mine. | Number of tons mined and shipped. | Average cost of mining, per ton. | Average number of men worked. | Daily wages. | Average amount mined and shipped per man per day. |
|---|---|---|---|---|---|---|
| 1852 | $0 70.81 | 17,134.08 | 14.06 cts. | 15 | $0 69 | 4 |
| 1853 | 0 76.25 | 57,025.15 | 11.04 | 30 | 0 69 | 6 |
| 1854 | 0 79.66 | 63,655.06 | 13.56 | 35 | 0 77 | $5\frac{8}{10}$ |
| 1855 | 0 95.67 | 33,607.09 | 17.04 | 25 | 0 77 | $4\frac{3}{10}$ |
| 1856 | 1 02.78 | 82,851.02 | 20.03 | 50 | 1 00 | $5\frac{3}{10}$ |
| 1857 | 1 02.57 | 73,406.03 | 21.02 | 46 | 1 00 | $5\frac{1}{10}$ |
| 1858 | 0 99.07 | 37,416.08 | 22.00 | 26 | 0 90 | $4\frac{6}{10}$ |
| 1864 | 2 28.00 | 165,405.00 | 33.66 | 90 | 1 56 | $5\frac{8}{10}$ |
| 1865 | 2 15.08 | 103,840.18 | 38.76 | 70 | 1 57 | $5\frac{14}{100}$ |

The apparent folly of a "free for all" system of mining must have been made apparent to the parties interested, for in 1864 the *Cornwall Ore-Bank Company* was formed, and Mr. Boyd, the present incumbent, appointed its superintendent, since which time all records have been carefully kept and mining reduced to one responsible system. From the very nature of the deposit already described, the mining problem is not a difficult one as yet, as all work is done above water level, as in a huge quarry.

The plan, in general, looks to an extension of a water level working face east and west from Furnace Creek, working in successive terraces, in advance of one another, while keeping the main idea in view. The general features of this system have already been referred to, and are sufficiently well exhibited on the map of the ore-banks (see Plate).

The railroad tracks within the mine of course advance with the mining, the shifting being generally done in the summer or fall of the year.

Between the track and the stopes a platform of untouched ground is left from 10 to 25 feet wide and about 6 feet high, for the purpose of saving the tracks and cars from the injury of falling ore after blasting, and for facility in loading the ore into the cars. The fine

surface-ore and the broken "run of mines" is of such a character that it can be as readily loaded as mixed rock and earth, and the workmen are alternately diggers and loaders.

The large lumps which result from the first blasts are wedged if soft enough or again broken by a blast.

The commercially prepared ore of course requires sorting into lump and fine ore (there is comparatively little waste stuff); but the *cost* involved in the transfer from the ore-stope to the cars is not necessarily much greater than loading so much mixed rock and dirt from an ordinary railroad cut, except in the weight of the material moved.

Skilled mining labor therefore, in the great open cuts, does not enter into the question of expense at all, except in so far as the Cornwall miner is required to judge exteriorly as to the grade of the ore, where assortment is necessary. And even here, if negligent or incapable, a watchful head miner can correct his error.

The miners work in gangs of about 35 or 40 men each, every gang having its head miner or boss. They are mostly diggers simply, as no hand-drilling is pursued in the mines.

In all the mining operations the precision, celerity, and, I judge, the economy of the work, is enhanced by the use of the compressed air drills.

The Cornwall drills, six in number, are of the Ingersoll type, 3½-inch cylinder hand-feed, and 6½-inch stroke. They approximate 300 blows a minute, and in this ore seem capable of making 150–160 feet per day of 10 hours, boring 3-inch holes.

The holes are usually drilled 5 feet apart and 12 feet deep, the charge of dynamite varying from 5 to 8 pounds per 12-inch hole, according to the nature of the ground.

The air-compressor is of the duplex type, with 20-inch steam cylinders and 21-inch air cylinders, both having a 48-inch stroke. The receivers furnish air at about 60 pounds pressure, and the furthest point reached in the mines is about 1800 feet from the compressor, when there is a loss of about 2 pounds pressure.

The drills are necessarily kept in advance of the mining, a series of holes being drilled and plugged ready for charging and firing as demand arrives; and herein consists the great usefulness of the air drills.

Formerly large quantities of the different classes of ore had to be kept in stock at the mines, ready for the varying demands of customers.

These ore-piles necessarily interfered with mining operations, and during cold weather, with exposure to snow and rain, the freezing of the mass added considerably to the total cost of shipment.

A force of about 200 men was employed in the fall of 1885, and the output was 35,000 to 45,000 tons per month,* or an average of 7 to 9 tons per man per day, allowing 25 days to the month, and with wages of 13 to 15 cents per hour. The total cost of mining ore, therefore, at Cornwall can hardly exceed 25 to 30 cents per ton, a figure which speaks volumes for this industry.

In conclusion of this subject, the following table is designed to show the approximate ore-tonnage won from this vast deposit between 1740 and 1886.

*Table showing the Approximate Production of Iron-Ore at the Cornwall Mines, from* 1740 *to* 1886.

| | TONS. | CWT. |
|---|---|---|
| 1740 to 1790, three furnaces, each 2000 tons annually, | 300,000 | |
| 1790 to 1848, six furnaces, each 2000 tons annually, | 700,000 | |
| April 1, 1848, to January 1, 1853, | 173,190 | 11 |
| January 1, 1853, to February 1, 1864 (date of formation of Cornwall Ore-Bank Company), | 1,351,717 | 05 |

| | TONS. | CWT. |
|---|---|---|
| 1864, 11 months, | 165,915 | 02 |
| 1865, | 114,802 | 11 |
| 1866, | 216,659 | 16 |
| 1867, | 202,755 | 03 |
| 1868, | 165,843 | 03 |
| 1869, | 173,428 | 16 |
| 1870, | 174,407 | 17 |
| 1871, | 176,054 | 15 |
| 1872, | 193,317 | 01 |
| 1873, | 166,782 | 06 |
| 1874, | 112,429 | 04 |
| 1875, | 98,924 | 17 |
| 1876, | 137,901 | 11 |
| 1877, | 171,588 | 19 |
| 1878, | 179,299 | 03 |
| 1879, | 268,488 | 06 |
| 1880, | 231,172 | 18 |
| 1881, | 249,050 | 01 |
| 1882, | 309,680 | 11 |
| 1883, | 363,143 | 10 |
| 1884, | 412,319 | 17 |
| 1885, | 508,864 | 06 |
| | 4,802,839 | 13 |
| Total from mines to January, 1, 1886, | 7,327,747 | 09 |

* Average for the year 1885 being 42,405 tons per month.

The records from April 1, 1848, through the courtesy of Mr. Boyd, are taken from the company's books, and are therefore reliably representative of the last 37 years mining.

From 1740 to 1790, a period of 50 years, an average has been struck of 6000 tons, based upon the consumption of three charcoal-furnaces using this ore.

From 1790 to 1848, a period of 58 years, the consumption was about 700,000 tons, based upon the product of six furnaces, all using Cornwall ore.

Though the grand total thus computed, *seven million tons*, seems a large one, it hardly begins to convey what the possibilities of this wonderful deposit really are.

The production of 1885, a total of 508,864 tons 6 cwt., is the demand during what may be termed an "off-year" in iron. It is the output from only about one-third of the power of the present plant, and it is fairly within bounds to say that a yearly output of 2,000,000 tons could be readily managed without the slightest interference to the workings, or any serious change in the mining plans; and this output could be kept up for at least 15 years before exhausting the amount of ore above water level in the three hills.

---

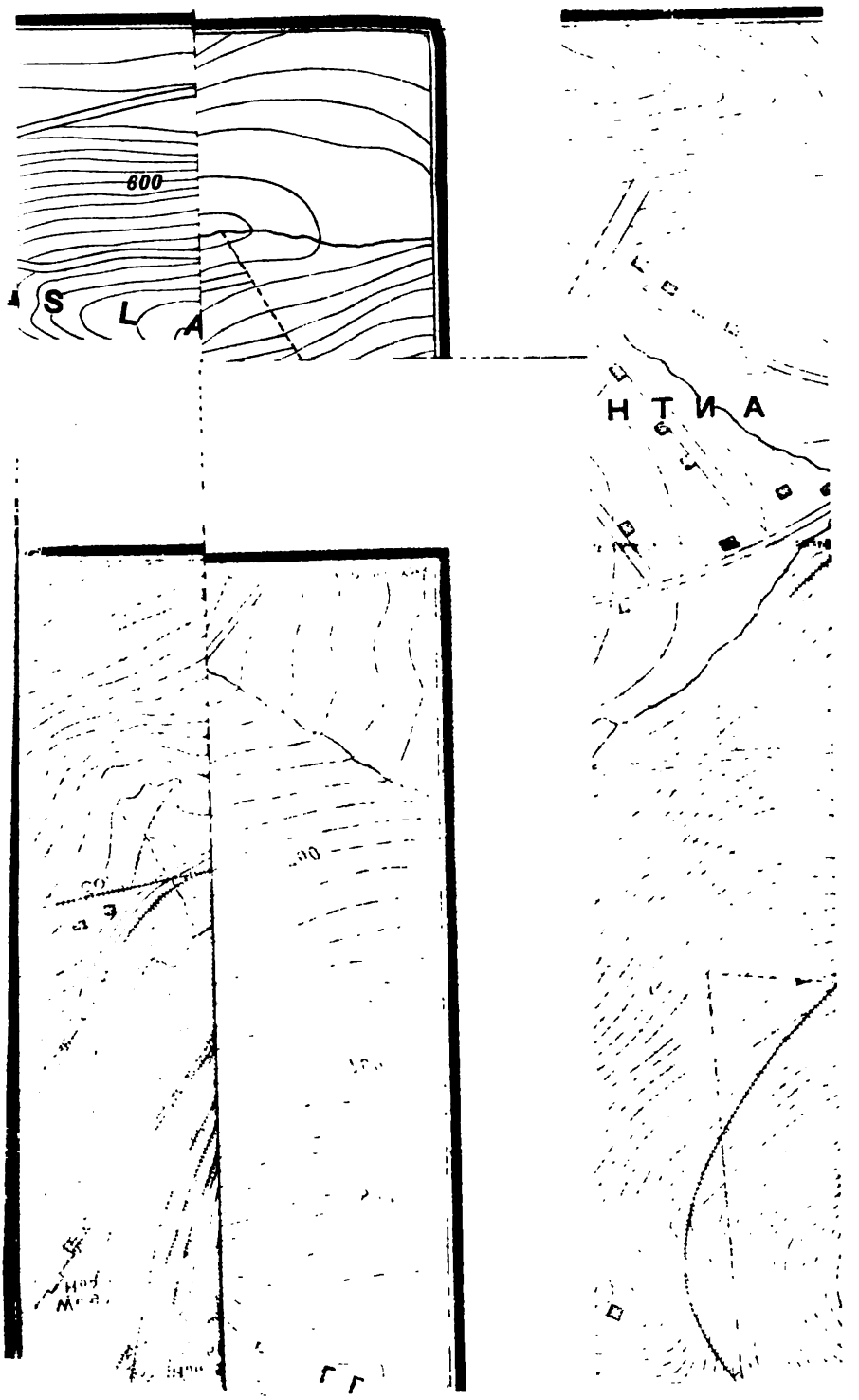
## *THE PRODUCT OF THE HIBERNIA IRON-MINE, N. J.*

BY J. WESLEY PULLMAN, PHILADELPHIA, PA.

It is stated by Dr. Tuttle in a paper read before the New Jersey Historical Society, that the celebrated Dickerson mine at Succasunna, Morris Co., N. J., yielded ore, about as early as 1710, for use at the Whippany forge, on Rockaway River, between Rockaway and Boonton. The ore was, for some time, free to all who chose to dig it. The tract embracing the Dickerson mine was taken up, on account of its minerals, in 1713 or 1714, by John Reading, who sold it in 1716 to Joseph Kirkbride.

John Jackson built a forge in 1722 on the Rockaway River a mile west of Dover. The ore here worked was probably chiefly from the Dickerson mine, but a portion may have been Hibernia.

Hon. E. D. Halsey, of Rockaway, N. J., writes me: It is quite possible that the ore was at first taken from the outcrop of Hibernia by anybody who wanted it. The property first had an *owner*, May


600
S L A
H T N A

M I L L
550
VALLEY
600
CO-EBROOK
CRASSY H. L
500
650

17, 1753, when it was "taken up" by Joshua Ball, the peculiar shape of the lot showing he intended to cover the vein, which must therefore by that time have had some value.

Between 1725 and 1730 a small forge was built by Job Allen where the upper forge now stands at Rockaway. The natural ore-supply for this forge would have been from Hibernia. Between 1730 and 1770 several other forges were erected on different streams in Morris county,—all made ore-blooms.

The Andover mine, part of a very extensive tract, was acquired by William Penn in 1714, by a warrant from the Council of Proprietors. About 1740 the Ringwood Company built a blast-furnace at Ringwood, near Greenwood Lake. A furnace and a forge were built before the Revolution at the Andover mine. This furnace was operated during the Revolution by direction of Congress, and the product was made into steel.

From 1753 to 1765 John Johnston had "Iron Works" at Horse Pound, now Beach Glen, 1½ miles below Hibernia, and doubtless used the Hibernia ore.

Peter Hasenclever, a German, who came to New Jersey in 1764, was a remarkable man in his day. He was the head of the London Company's Works; he built a furnace and a "finery forge" near Charlotteburgh, and introduced many improvements in the methods of making and refining iron; he was the means of bringing over John Jacob Faesch, an iron master, who after *serving his time*, leased the Mount Hope mines for fifty years, and built the furnace there in 1772. In the year 1765 the "Adventure" furnace was built at Hibernia; and during the Revolution shot, ordnance and other iron supplies were made here for the Continental army. This furnace (sometimes called the "Horse Pound Furnace") is identical with the Hibernia furnace, which passed into the exclusive possession of Lord Stirling* (William Alexander), a native of New York city, between 1771 and 1773. Hon. E. D. Halsey states that among the laws of New Jersey for 1777 is an act exempting men employed at the Mt. Hope and Hibernia furnaces from military service; and reciting the necessity of providing the Continental army and navy with cannon, shot, etc. from these works. (See letter marked IV.)

In 1775 and 1776 Joseph Hoff was the manager of the Hibernia

* Member of the Provincial Council and Surveyor-General of New Jersey; March, 1776, commissioned by Congress as a brigadier-general, captured at the battle of Long Island, promoted by Congress, February, 1777, to be a major-general, and served with distinction until his death in 1783.

furnace, and in 1777 was succeeded by his brother Charles Hoff, Jr., as appears from old letters to Lord Stirling, and to Col. (afterwards General) Knox, chief of artillery, and a member of Washington's staff.

This Chas. Hoff, Jr., manager of the furnace from 1777, left two sons, Charles and Joseph T. Hoff, who were born at Mt. Pleasant. Charles died in 1860, and Joseph T. in 1871. I am indebted to their nephew, Mr. S. S. Beach, for the loan of a book containing copies of many of the original letters of both Jos. Hoff and Chas. Hoff, Jr., concerning the operations of the Hibernia and Mt. Hope furnaces when employed in casting cannon and shot for supplying the American army.*

The following letters may serve as samples:

I.

HIBERNIA 29 March 1776.

MESS$^{rs}$. MURRAYS.—

I wrote you last post about powder particularly and also mentioned that I thought it highly proper that some Rum, Molases and Salt should be at Eliz Town for us as matters are like to come to such extremitys at New York and you know our only resource is from you—matters are bad enough at the best these times, but when the Furnace is in Blast, if we should want the common Necessarys of Life we should be undone. * * * *

Your most Obed.$^{t}$ Serv.$^{t}$

Jos. HOFF

II.

HIBERNIA October 1$^{st}$. 1776.

SIR

Not having heard anything from you respecting the Canon we were ordered to make by Mr. Ivers, I had stoped doing any thing at the business for some time, but am now prepareing to go on again, having frequently heard that Canon of every kind are much wanted—

I have now an oppertunity of employing a good set of Moulders (of which the bearer is one) and would willingly engage to make a quantaty of shott of any kind, and try at some Canon say, of the 6 and 9 pounders (will therefore be oblig'd to you to inform me what kind; are wanted, what quantaty, and the price that will be given, where to be delivered &c.—it would suit me best to deliver them at New Ark.

We are persuaded or Iron will answer for Canon, as wee have prov'd the first wee made to be good, if wee do anything at this business, wee must get the moulds of each size from you.—

I am your most hum$^{b}$. Serv.$^{t}$

Jos. HOFF

To Coll Knox at Fort Washington in the State of New York.—

---

* Mr. Pullman exhibited the original letter-book to the members present at the Pittsburgh Meeting.

## III.

HIBERNIA 14 Nov.r 1776

COLL KNOX.—

I wrote you a few days past that in Consequence of your letter of 10 ult.° we had got everything in readiness and had cast several tons of the Shott but that it was altogether out of my power to get them carted—We have now upwards of 35 tons made and as the Furnace is doing no other Business shall I hope compleat the order in a short time, every preperation of moulds, flasks &c for the Grape shott is now finish'd and we shall soon have a good assortment of each kind—As the Iron work Business is attended with a great expence and the produce of the furnace now altogether for the public use, it falls heavy on us to carry it on, I must therefore take the Liberty to request you will be pleas'd to represent the matter properly to the Q M Gen.l. and send me by my brother £1000 in order that I may be enabled to Support the Business and compleat the Jobb with conveniences—I could wish some Steps might be taken to get the Shott carted, for unless it can be done by—command of people in power I don't see how it will be effected—

I am &c

JOS. HOFF

## IV.

HIBERNIA FURNACE 27th July 1777

HON.d Sir—

I understand from Col. John Munson of the Militia for this part of the County of Morris that there is to be a draft made out of it in a few days hence and among the rest the Workmen at this Works as has told me that nothing but an order from under your excellenceys own hand would render it consistent with his duty to excuse them I take the Liberty of beging your excellencies Indulgence in this matter so far as to give Col. Munson such orders in writing for the reasons which I will hereafter mention Gen.l. Knox of the Artillery thinking it likely that a Quantity of Military Stores would be wanted for the present Campaign concluded this works must be employed in making a part of em and in order for that gave Orders that every preparation should be made for putting the furnace in blast which has been done with a considerable expence and should the Workmen be required to leave the business in its present situation great damage must result from it and render it Impossible to comply with the Aforementioned Order for want of Stock of Coals & Oar We are boaring out & preparing for tryall 4 or 5 Canon of 3 pounders and are of opinion they will prove good which would be of great use in the Artillery—I enclose y.r Excellency the Exemption given by his Excellency Gen.l Washington at the time of the above Order from Genl. Knox we made the last year for publick Service upwards of One Hundred & Twenty Tons of Shott of different kind many Tons of which are here Still I shall ever think myself happy and in my duty to my Country to contribute by every means in my power in Opposing that Tyrannical Spirit which is now exhibited by the british Nation and Shall ever be ready to Obey any command from your excellency for that end.

I am Yr. Excellenc. most Obed.t & Very Hble Serv.t

CH.e. HOFF, Jun.r.

GOVERNOR LIVINGSTONE.

I am unable at this time to give even an approximate estimate of the product of the Hibernia mine from 1750 to 1854. The memory of the oldest inhabitant seems a trifle defective on this subject, and no

satisfactory records exist. In 1850 no ore was mined except to supply the forges at Beach Glen and Powerville. The old buildings and the furnace were in ruins, and but one house was near the mine.

Mr. George Richards, of Dover, N. J., Mining Supt. of the Glendon Iron Co., reports the quantity of ore carted by their company from June 1st, 1854, up to the opening of the Hibernia Mine R. R. in 1864, as 84,155 tons, 10 cwt., 3 qrs.

The Lower Wood (Hibernia) mine was leased by the Trenton Iron Co. in 1859, and the quantity of ore raised by them up to January 1st, 1864, was 20,365 tons, 4 cwt.

The total ascertained product of the Hibernia mines between 1854 and 1864 was say 104,521 tons.

The actual shipments of ore from these celebrated mines for the twenty-two (22) years from January 1st, 1864, to December 31st, 1885, inclusive, foots up, 1,641,437 tons, 16 cwt. Estimating the stock-piles at Hibernia mines and docks, January 1st, 1886, as 75,000 tons in excess of the stocked ore January 1st, 1864, we have a total of ore actually raised during the 22 years, 1,716,437 tons, 16 cwt., being an average annual yield of 78,020 tons.

Although this by no means represents the annual economic capacity of these mines, as during several periods of years the depression in the iron business, coupled with the rapidly growing import of foreign ores, limited the output to less than one-third of the developed productive capacity,—nevertheless the average annual product, say 78,000 tons, very considerably exceeds the output of any other mine in the State of New Jersey.

A brief outline therefore of this purely commercial or statistical position of the Hibernia mines, will not be without interest to the members of the Institute.

As Secretary of the Hibernia Mine R. R. Company, the author of this paper has the precise figures of all transportation of material going east to the mines, as well as the west-bound tonnage, chiefly iron-ore, destined to the blast-furnaces of the Lehigh district.

The total quantity of coal sent to Hibernia for steam purposes, including that used for pumping-engines, compressor-plants, and a small quantity for smith-work for the twenty-two years, 1864–'86, is 59,133 tons 1 cwt. Dividing by the output of ore, 1,746,437 tons 16 cwt., we have an average consumption of $77\frac{1}{10}$ lbs. of coal for each ton of ore raised.

It would be interesting to have from gentlemen of the Institute,

representing iron-ore mines, corresponding figures showing their actual consumption of coal per ton of ore produced.

However, that such figures may be of value for comparison, assuming the unwatering duty to be about equal, it must be borne in mind that almost the entire output of 1864–'86 at Hibernia is derived from *underground* work, driven through very hard material, both ore, vein-matter, and rock; also, that while the ore-bodies are of fair size and extremely persistent and reliable for almost the entire length worked on the vein, the ore is not so easily or cleanly broken as in other mines of our State—notably the Richards, Allen, and Mount Pleasant.

The Hibernia ore-bodies are more frequently penetrated by horses, making it necessary to break and move a large amount of rock to raise the full quantity of merchantable ore from any given length of ground.

On the other hand, mines of some importance in Morris county were formerly worked continuously and with fair commercial success, where the waste-matter broken and removed far exceeded the proportion obtaining at Hibernia.

These ores are of two classes: 1st. Lean and silicious ores, free from sulphur and running from 40 to 48 per cent. iron, after careful cobbing, but *purely Bessemer* as to *phosphorus*; and 2d. Sulphury ores, containing from 1½ to 4 per cent. sulphur,* but running 50 to 58 per cent. metallic iron, somewhat irregular in phosphorus, but rarely going above .065 per cent. and frequently down to .035 per cent. and less. A very considerable quantity of these ores was worked up to 1874–75 for Bessemer iron, and being sold at a slightly better price (per unit of iron) than the phosphatic ores, the mines referred to enjoyed a moderate degree of success.

As soon as the foreign import attained considerable proportions, both New Jersey and New York "acid Bessemer" ores were sold for ordinary foundry- and mill-irons, and the incentive to the development of the native Bessemers ceased.

In passing it may be said that the Hibernia ore forms the principal basis of both Glendon and Andover forge-irons, which usually command from $1.00 to $1.50 per ton higher price in the Philadelphia and Eastern markets than ordinary Lehigh brands.

Prof. Pumpelly, compiler of mineral statistics United States Cen-

* This percentage of sulphur is readily reduced by the Taylor-Langdon gas-roaster to 0.5, and with careful work to 0.30.

sus of 1880, gives the following iron and phosphorus determinations from Andover-Hibernia (Lower Wood) and Glendon mines.

| No. | Fe. | P. |
|---|---|---|
| 1 | 58.22, | 0.407. |
| 2 | 57.27, | 0.139. |
| 3 | 53.78, | 0.364. |
| 4 | 56.00, | 0.223. |

The analysis of Willis (Bethlehem) Hibernia gave Fe 47.82, P 0.343.

According to the same authority, nineteen important mines are quoted, including the Glendon-Hibernia, as producing in 1880, the census year, 2,460,845 tons.

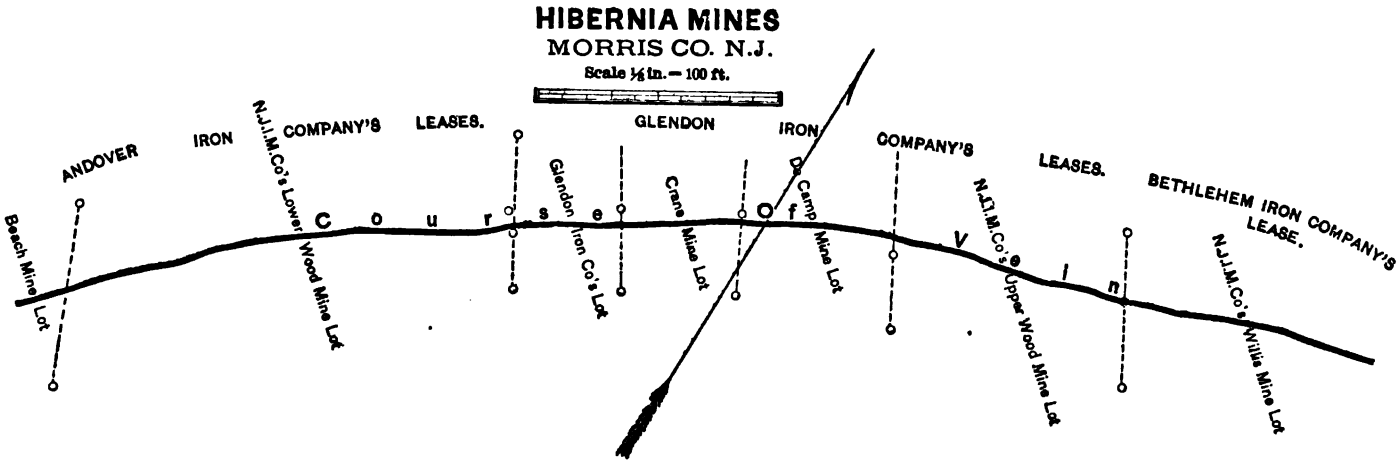
The number of men employed was 6355, being an average of one man for an output of $387\frac{2}{10}$ tons.

The New Jersey mines included are the Glendon-Hibernia and the Mount Hope, the two producing 136,002 tons, and employing 744 men, making the output per man only $182\frac{8}{10}$ tons. At first sight it appears difficult to account for so great a disparity of annual yield per man, but the statistics given of the Cornwall ore-bed product go far to the solution.

The yield at Cornwall is given as 280,000 tons, and the number of men employed at 135, an average output per man of 2,074 tons; this, in connection with the opening of new mines of the Menominee district of Lake Superior, chiefly of soft, easily-dug hematites, and the extraordinary yield, in proportion to number of men employed, of the Old Bed and No. 21 mines at Port Henry, N. Y., suffice to explain the comparatively high labor-cost of our best New Jersey mines.

In no district does so large a proportion of the ore-cost go directly to mine-labor; and no portion of our mining territory is exposed so rudely to the competition of foreign ores, which are landed at Hoboken, Elizabethport, and the Amboys, and thence hauled by competitive railways directly across the ore-beds at special mileage rates, unattainable by New Jersey operators from the Morris county shipping points.

The development of both the New York and the New Jersey mines is seriously retarded by the influx of foreign ores at a comparatively low duty, and any temporary scarcity of Eastern "acid Bessemer" ores is due to the same cause. Intelligent iron-masters, the purchasers and consumers of ore, are beginning to appreciate the vital fact that *home* mines are the only safe and stable source of supply, even in time of general peace here and abroad. When a quick demand sets


HIBERNIA MINES
MORRIS CO. N.J.
Scale ½ in. = 100 ft.
ANDOVER IRON COMPANY'S LEASES.
GLENDON IRON COMPANY'S LEASES.
BETHLEHEM IRON COMPANY'S LEASE.
N.J.I.M.Co's Lower Wood Mine Lot
Glendon Iron Co's Lot
Crane Mine Lot
De Camp Mine Lot
N.J.I.M.Co's Upper Wood Mine Lot
N.J.I.M.Co's Willis Mine Lot
Beach Mine Lot
Outcrop of Vein

in, sending the import of foreign ore materially above half a million tons, Spanish, Italian, and African ores are promptly advanced in price by the London owners or agents; freights go up, from ballast and usual return-cargo rates, to 15*s.* and 20*s.* per ton; and the American consumer remits enormous sums to our British brethren, one-half of which, judiciously expended upon the opening and development of home mines, stretching in an almost unbroken line from the Delaware to the St. Lawrence, would soon render us independent of any foreign supply.

As stated by Professor Pumpelly, the output of both the New York and the New Jersey mines during the census year, one of great activity in the iron and steel trades, scarcely reached one-half of the actual developed capacity. 1880, New Jersey: maximum yearly capacity of production, 1,487,829 tons; actual product, 754,872 tons. New York: maximum capacity, 2,149,129 tons; actual product, 1,239,750 tons.

As before shown in this paper, the average yearly product of the Hibernia mine (1864–'86), say 78,000 tons, is very much below the developed capacity. In 1880 the output was 145,029 tons; in 1881 it was 144,098 tons; in 1882 it was 135,652 tons: an average for the three years of 141,893 tons per annum. Even as far back as 1873 the year's product was 114,000 tons. These mines would now readily produce 200,000 tons per annum, if the demand existed for this quantity.

The following is a complete analysis of the Hibernia ore. (Sample and analysis by L. C. Bierwirth, of Dover.)

| | |
|---|---|
| 1. Soluble in acids: | |
| Magnetic oxide of iron, | 82.371 |
| Bisulphide of iron, | .711 |
| Alumina, | 3.650 |
| Lime, | 1.175 |
| Magnesia, | .390 |
| Phosphoric acid, | .803 |
| Carbonic acid, | 1.045 |
| Fluorine, | trace |
| 2. Insoluble residue: | |
| Silica, | 6.925 |
| Protoxide of iron, | .878 |
| Alumina, | 1.525 |
| Lime, | .407 |
| Magnesia, | .608 |
| | 100.488 |
| Total metallic iron, | 60.66 per cent. |
| Phosphorus, | 0.3524 " |

## *THE MICROSCOPIC STRUCTURE OF CAR-WHEEL IRON.*

BY F. LYNWOOD GARRISON, F.G.S.

THE study of the microscopic structure of the iron of car-wheels, which it is the aim of this paper to describe, was made at the suggestion of Dr. Dudley, whose paper upon the constitution of cast-irons (page 795 of the present volume) should be read in connection with this one. Although the two wheels referred to in that paper possess nearly an identical ultimate chemical composition, they possess, as Messrs. Dudley and Pease have shown, physical properties so widely different, as to make one of them nearly worthless for the purpose for which it was cast. Considering the chemical similarity, such a marked difference in strength cannot but be very striking, and goes to show how little reliance can be placed upon chemical analysis alone, if *not properly interpreted.* I say "not properly interpreted," because I believe that very few analyses of iron or steel are thus fairly dealt with. That an analysis may read so much of one thing and so much of another, tells us very little as to the properties of the metal; for these are determined to a large extent by the conditions and relations in which the elements are present. To the unaided eye the difference between the two wheels under consideration is not striking. The inferior one would be described as light gray, and the other as somewhat darker. Upon careful examination of an etched fragment, however, the difference in structure will be found to be very marked, as may be seen in Figs. 1 and 2 (produced from photographs by the Ives process).

It is exceedingly difficult to produce a photograph giving a fair notion of the appearance of the metal under the microscope, so as to give to persons not familiar with microscopical study, a proper appreciation of what a microscopist would consider a decided difference in structure. I would, therefore, urge any one especially interested in this subject, not to depend upon the photographs of others, but to prepare and etch the specimens himself, and then examine them with a good microscope.

As is well known, iron possesses the property of uniting with a number of elements, forming products which are either highly intimate mixtures of several substances, or else compounds of an indefinite character. Indeed such mixtures may be regarded as alloys, or as Matthiessen puts it, "solidified solutions of one sub-

stance in another." Of all the elements commonly associated with iron, carbon and, possibly, silicon have the peculiar property of being capable of existing in the compound in two distinct conditions, one in an amorphous or combined state, and the other as graphite in mechanical mixture with the iron. From the recent researches of Sir Frederick A. Abel,* Dr. C. B. Dudley, and F. N. Pease, of Altoona, Pa., there seems to be much to strengthen the belief of the existence of carbon in iron in a third and combined form, as a "carbide of iron." This compound is described as a "definite product capable of resisting the oxidizing effect of an agent which exerts a rapid solvent action upon the iron through which this carbide is distributed. It is gray in color, and seems to exist in small granules, affecting the continuity of the metal."

That such a compound of carbon and iron exists as such in the metal, is by no means proved; and so far as the writer's researches with the microscope have extended, there seems to be little evidence for or against such a hypothesis. It is a generally accepted belief that, when present in considerable quantity, graphitic carbon has a decided effect in decreasing the strength of cast iron. Such is certainly the case when a certain limit has been passed; but just what this limit is, it would be difficult to determine. It is very probable, however, that this limit is affected by the amounts of other elements present, and by the conditions under which the metal has been fused and cooled, or treated at a temperature below its melting-point. Thus it is found that hardened steel yields no sensible residue of graphite when dissolved in acids; but if, on the other hand, the same steel be annealed, a very considerable amount of graphitic residue will be obtained. It also seems that a temperature much higher than that of the melting-point of the metal is necessary to produce graphitic iron, and that slow solidification after fusion is the condition most favorable to the separation of the graphite in flakes or laminæ. On the other hand, rapid solidification or chilling favors the retention of the carbon in the combined or amorphous state, and produces a hard white and highly crystalline iron, melting at a temperature considerably lower than gray iron. When the amount of manganese present is relatively large, the separation of graphitic carbon takes place to but barely an appreciable extent, the resulting mass, after fusion and solidification, being highly crystalline, and with fractured surfaces of great brilliancy, whence the name of spiegeleisen.

* *Journal of the Iron and Steel Institute.*

It seems almost certain that there exists no ordinary iron or steel in which *all* the carbon is contained in either one condition or the other, but that it always exists in the two (or three) conditions together, and that upon the relative proportions of these depends, in great degree, the quality of the metal. Thus in cast-iron, if the relative amount of combined carbon is large, we have a white iron, but if small, a gray graphitic iron with quite different physical properties. Car-wheels being made usually from the best grades of pig-iron can be described as gray iron, the periphery or "tread" alone being white or chilled, and, of course, between the two, a small intermediate zone, containing varying proportions of combined and graphite carbon. In nearly all varieties of gray cast-iron a very marked and characteristic development of the graphitic carbon will be observed when a fragment of the metal has been carefully ground, etched, and microscopically examined. As will be shown below, the existence of the graphite in strong and well-defined lines and plates, has a most important bearing upon the strength of the metal.

In Fig. 1, taken from a photograph showing the microscopic structure of the good car-wheel iron, the plates and lines of graphite are very marked, and appear as an irregular mass of small, black lines, which might be likened to a number of small, black worms wriggling and squirming throughout the metal. The surrounding mass of metal presents a compact, granular, non-crystalline structure, frequently containing cavities, due to occluded gases or air. It seems impossible to produce castings altogether free from these defects—and it needs not always the microscope, or even a magnifying glass to detect them—but it is doubtful whether their absence would prove of much benefit to the metal for practical purposes. On further examination of Fig. 1, it will be observed that very little of the graphite occurs in isolated irregular patches, as will be seen to be almost always the case in the poorer grades of cast-iron.

In Fig. 2 we have the structure of the poor car-wheel iron. It will be noticed that, although the mass of the metal itself appears to be the same as that of the good wheel, the well-developed and prominent graphite-plates are absent, and are replaced by the graphite in irregular and somewhat isolated patches of comparatively large size, and without any regular grouping. This peculiarity seems general and characteristic of the poorer grades of cast-iron. In nearly all cases metal which shows it is unreliable, lacking the toughness and durability of the better grades.

In Fig. 3 is exhibited a similar structure, being that of a weak and almost valueless pig-iron, containing 4.6 per cent. of carbon,

FIG. 1.

Good Car-wheel Iron.

3.22 per cent. of which is present as graphite in irregular patches, as in Fig. 2, the metal mass itself being compact and granular.

FIG. 2.

Poor Car-wheel Iron.

In Fig. 4 is shown the structure of a high-grade hot-blast charcoal pig-iron; the similarity of its structure with that of the good wheel

is quite apparent, except that in the latter the graphite-plates are somewhat larger and more prominent.

FIG. 3.

Weak Pig-iron.

These facts indicate that the development and distribution in well-defined lines or plates of the graphite carbon is at least as important

FIG. 4.

Hot-blast Charcoal-iron.

a factor of quality, up to a certain limit, as its total amount. Although it is generally supposed (and undoubtedly with good reason,

when the limit has been passed), that the presence of graphite in quantity renders the metal weak, I have found, in almost all cases where the iron lacked strength, that the development of the graphite in plates was only incipient, and that the graphite present existed in irregular patches or clusters of great variety in size and shape.

Of course, this connection between the strength of the metal and the form and distribution of its graphitic contents, even if proved to be an invariable one, need not necessarily represent the only, or the whole, explanation of the case of the two car-wheels now under consideration. Nor is the question answered, to what cause the difference in graphite-distribution is due. Perhaps the following facts may throw some light upon the problem.

Percy* says, that the mode of existence of the carbon in iron and steel is, to a certain degree, determined by the conditions under which the solid metal has been heated and cooled at temperatures very much below its melting-point. This point is best illustrated by the annealing of hard steel, and its subsequent treatment with acids, before alluded to. Again, according to Karsten, it seems that even if cast-iron is allowed to cool with the utmost slowness after fusion, it is not then converted into gray iron unless it has been melted at a much higher temperature than was required to bring it to a liquid state.

The following are the analyses of the two wheels, as given by Messrs. Dudley and Pease:

| | Good Wheel. | Poor Wheel. |
|---|---|---|
| Total carbon, | 3.84 per cent. | 3.53 per cent. |
| Graphite, | 3.30 " | 2.36 " |
| Combined carbon, | 0.54 " | 1.17 " |
| Silicon, | 0.69 " | 0.65 " |
| Phosphorus, | 0.43 " | 0.52 " |
| Manganese, | 0.13 " | 0.12 " |
| Sulphur, | 0.12 " | 0.19 " |

From these analyses, it will be observed that the poor wheel contains 0.07 per cent. more sulphur than the other. Bell,† in speaking of the influence of sulphur upon cast-iron, observes that, "speaking in general terms, it seems probable that the presence of this element interferes, in some way, with the separation of carbon in the graphitic state, a condition which appears essential to the formation of soft iron."

Although it may not apply in this particular case, it is a well-

* *Metallurgy of Iron and Steel.*

† *Principles of the Manufacture of Iron and Steel*, p. 103.

known fact that silicon, when present in considerable quantity, seems to favor the separation of graphitic carbon, and that the grayest iron is apt to be the richest in that element. As will be seen from Dr. Dudley's paper, the small difference in the amounts of phosphorus present in each wheel, does not, in all probability, affect the result, so that its presence need hardly be considered.

The above citations point to the conditions of fusing and cooling, and to the relative proportions of ingredients other than carbon, as controlling the separation of graphite. Dr. T. M. Drown* has suggested a very beautiful hypothesis, according to which the amount of graphite separated in any given instance is proportional to the time consumed by the pig-iron in passing through a limited range of temperature, probably near the point of solidification. Adopting this hypothesis, may we not further imagine that the other ingredients, affecting the melting-point of the compound, affect also the limits of this range of temperature; but that, these things being equal (as they almost are in the case before us), the conditions of casting and cooling may decide the quality of the product, by determining not merely, as Dr. Drown suggests, the amount, but also the form and distribution of the segregated graphite?

---

## *THE CLAPP-GRIFFITHS CONVERTER—LATER PRACTICE AND COMMERCIAL RESULTS.*

BY J. P. WITHEROW, PITTSBURGH, PA.

THE plant of Messrs. Oliver Brothers and Phillips, the only one in operation until January, 1886, has not been available for any further experiments since those of Mr. R. W. Hunt, described in his paper on the subject, at the Chattanooga meeting. Continuous working has, however, led to important improvements in plant, and furnished valuable results in practice.

The difference between the converter and plant of 1884, as illustrated in our *Transactions*, vol. xiii., p. 759 and following pages, and those of 1885, may be observed in Plates I. and II. accompanying this paper. Plate I. gives the elevation and plan, in half-section, of one of our latest 3-ton converters. Plate II. gives a plan of the general arrangement of a plant adapted to turn out slabs, blooms, and billets for the general market. The letters on Plate I. refer to the following parts:

---

* *Transactions*, vol. viii., p. 41.

A, wrought-iron body and nose; B, wrought-iron movable bottom, with wind-box of flanged steel; C, wind-box; D, tuyere-door; G, tapping-spout; H, charging-spout; I, cinder-opening; K, blast-nozzle and connection; L, bye-pass and regulating-valves; M, spark-screen; N, platform; O, bottom-handling carriage; P, hydraulic ram for lifting bottoms; Q, base-plates and beams for lifting-ram; R, supporting housings; S, anchor-bolts; T, anchor-plates.

These illustrations show the improved plant of Messrs. Oliver Brothers and Phillips, which has given satisfactory results. Natural gas, furnishing a convenient means for the thorough drying of the bottoms, has enabled them to stand a large number of heats—as high as 89, which is far beyond the best practice elsewhere; and a greater cupola capacity (even yet below the requirements) has assisted the production of a larger output—the number of blows per turn ranging from 40 to 50, giving a double turn from 130 to 150 tons of product per 24 hours. This large product cannot be kept up at present, for lack of facilities to work it. The erection of a blooming-mill promises, however, to permit the converting department to be run to its maximum capacity, with corresponding gain in economy.

The details of practice given below are from these works; but other works of later design involve extensive alterations and improvements in the details and arrangement of the plant. The Glasgow Iron Company's works, at Pottstown, Pa., may be cited as the most modern Clapp-Griffiths type, in a case where the design is not hampered by local circumstances or a necessary connection with existing machinery and mills. It has not been deemed necessary to accompany the publication of this paper with engravings of this plant;* but a description may be permitted here.

The complete plant is contained in two buildings of very moderate size, the iron-converting house being 120′ long by 50′ wide, while the engines, boilers and ovens are covered by a structure 100′ by 40′, the engine house brick, and the rest iron. Ample yard-room is provided by placing the small building some 60′ from the converting-house, the drying-ovens standing opposite the converters, and thus allowing rapid and convenient transfer of the hot bottoms. Through this yard runs a track for the delivery of the raw materials, elevated enough to reduce rehandling to a minimum.

The engine- and boiler-house presents nothing further than a con-

* The drawings of the Glasgow works were exhibited at the Pittsburgh meeting, and copies can be furnished by the writer to those who may be sufficiently interested to ask for them.

venient and well-adapted arrangement; but several features of the converting works are worthy of notice, and some are quite novel.

Each of the cupolas is fitted with two filling-doors, on a level with the charging-platform, so placed that the radiation of heat therefrom is directed to the corners and sides of the charging-floor, thus exposing the fillers as little as possible, and yet making it convenient to use side-dumping wheelbarrows.

For protection and economy of floor-space the charging-scales are placed below ground. Over their platform is placed a neatly-fitting plate-iron guard, which also encloses and protects the stand upon which the charging-ladle rests to be filled and weighed. When ready, this ladle is lifted from its stand by the charging-crane, swung around to position in rear of the converter, raised till the hooks on the tipping bars are engaged, then by the further raising of the crane and racking out the horizontal harness, the contents of the ladle are rapidly and completely emptied into the converter; the lift of the crane being adjusted so that its extreme limit is reached before any dangerous stress is set up in the hooks. As the crane is required only a portion of the time for handling the ladle and performing the charging operation just described, it has been also fitted up to assist in handling the converter-bottoms, for which it is very conveniently located, although the bottom for either converter may be readily attached and removed without its use. The jib of this crane has, therefore, two buggies, that one nearest the outer end supporting a heavy and well-braced vertical harness, terminating in two massive ladle-hooks. A horizontal harness leads back from this to the mast, where it is supported and actuated by a pair of racks and pinions that are operated by a large hand wheel, conveniently accessible from a platform fastened to the mast and turning with it. The travel of the buggy together with the swing of the vertical harness gives the ladle a movement of a little more than five feet. To the second buggy a hanger is attached, supplied with a yoke fitted to carry a vessel-bottom, the crane having lift enough to conveniently transfer a bottom from one car to another and, by a connection between the horizontal harness and the hanger, a rotary motion can be given to the bottom while suspended, thus facilitating its adjustment upon the car.

For raising and lowering the bottoms, each converter stands over a powerful hydraulic jack, with its ram provided with a turntable head. Rising through the car, this head receives the bottom and allows it to be freely revolved as desired. The bottom, when detached, is placed upon its car, and need not be removed until again presented to the converter. The handle of the valve for working this jack is

placed in the recess of the converter-housing, where, while perfectly protected, it is always at the hand of the bottom-man when engaged in setting or withdrawing a bottom. In like manner, the handle of the valve operating the charging-crane is placed in a location from which the various functions of that crane may be best observed—that is to say, between the converters and just back of the ladle-crane. Here the operator is out of the way, but still has a perfect view of the work he is called upon to perform.

In the arrangement of the casting-pit, and in the design of the casting- and the ingot-cranes, the most approved practice found in the modern Bessemer plant has been followed, or adapted to meet the special requirements; and it should be noted that all is so harmoniously arranged that with the 100 to 150 tons of metal passing through the works daily not a pound of it, after charging the cupola, has to be lifted by the human hand.

The plant of the Western Nail Company, Belleville, Ill., of which Gen. W. H. Powell is president, has been completed and is now in full and successful operation, the first of the modern series. At Port Henry, the Witherbee plant is finished and starts this week. At Pottsville and Pottstown two others are nearing completion, the former of which will also commence operations this week. Three more are in progress, those of Col. Henry McCormick, at Harrisburg, the Lickdale Iron Company at Lebanon, and the E. and G. Brooke Iron Company at Birdsboro. This number of plants actually under way goes far to show that the ironmasters of the country are awakening to the fact that this process offers exceptional advantages.

In regard to the use of small ingots, those wishing them for nail-slabs—say 50″ long by from 13″ to 16″ wide by 5″ thick—can rest assured that they can be economically made, as shown by the example of the Western Nail Company's practice to-day. Smaller ingots in like manner can undoubtedly be produced. If, however, the maximum capacity of the plant is desired, it will be found more economical to use regular 10″ or 12″ moulds, provided the mechanical appliances for their manipulation constitute part of the plant.

Dealing with 2 to 3 tons per blow, this process avoids many of the objections urged by Bessemer men against small ingots; and we think the question practically solved for nail-mills, using from 50 to 80 tons of steel per day. Furthermore, the experience that Gen. Powell has already had, at the Western Nail Company's plant, fully establishes the fact that but trifling and inexpensive alterations are necessary in most nail-mills to enable them to fully utilize this process.

The following data, from practice at the works of Messrs. Oliver Brothers & Phillips, speak for themselves:

For eight consecutive weeks, while on single turn, the average number of blows per day was 36; and this is taking Saturday into consideration as only half a day—never more than 25 heats being made on that day. The maximum and minimum week's runs were as follow: Maximum—Monday, 34 heats; Tuesday, 35; Wednesday, 51; Thursday, 45; Friday, 40; Saturday, 25; total for week, 230 heats. Minimum week—Monday, 36 heats; Tuesday, 36; Wednesday, 29; Thursday, 35; Friday, 36; Saturday, 22; total for week, 194 heats.

On Monday, October 12th, the works were started on double turn, and since then have been doing, without extra effort, what, in the light of previous experience, has been regarded as extraordinary work. The following record, furnished by the manager, Mr. George E. Tener, covers a period down to October 24th.

*Blower's Report, Steel Department, Oliver Brothers & Phillips, George W. Bryant, Superintendent.*

| | DAY TURN. | NIGHT TURN. | |
|---|---|---|---|
| October 12, | 28 blows. | 36 blows. | |
| " 13, | 37 " | 38 " | |
| " 14, | 37 " | 38 " | |
| " 15, | 37 " | 33 " | 8 bottoms used. |
| " 16, | 31 " | 30 " | |
| " 17, | 31 " | | |
| | 201 | 175 | Total, 376. |

| | DAY TURN. | NIGHT TURN. | |
|---|---|---|---|
| October 19, | 35 blows. | 28 blows. | |
| " 20, | 35 " | 40 " | |
| " 21, | 42 " | 38 " | |
| " 22, | 39 " | 39 " | 9 bottoms used. |
| " 23, | 35 " | 32 " | |
| " 24, | 22 " | | |
| | 208 | 177 | Total, 385. |

Previous to October 12th, the regular charge blown was 4000 pounds, but on that day it was increased to 4500 pounds, with perfect satisfaction, and since that time has remained at the latter weight. From this record it is safe to say that the product, with the present weight of each blow, can easily be held at from 150 to 175 tons daily, with corresponding decrease in labor in cost per ton.

The following is a more recent statement:

*Report of Operations of Oliver Bros. & Phillips's Converting Department. Week ending February 6th, 1886.*

| Date. | | Turns. | No. of Blows. | Materials charged. | | | | | Steel prod'ed. | No. bottoms used. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Pig. | Scrap. | Coke. | Lime-stone. | Ferro. | Pounds. | |
| Monday, | Feb. 1st.. | Day. | 42 | 123,620 | 16,200 | | | | 122,400 | |
| " | " " | Night. | 44 | 135,970 | 17,810 | | | | 134,650 | |
| Tuesday, | " 2d .. | Day. | 39 | 123,750 | 6,875 | | | | 120,900 | |
| " | " " | Night. | 41 | 128,500 | 23,325 | | | | 120,400 | |
| Wednesday, | " 3d.. | Day. | 42 | 130,900 | 15,825 | | | | 125,580 | |
| " | " " | Night. | 45 | 134,300 | 18,225 | | | | 137,250 | |
| Thursday, | " 4th. | Day. | 42 | 124,100 | 15,500 | | | | 124,740 | |
| " | " " | Night. | 41 | 124,800 | 22,325 | | | | 120,540 | |
| Friday, | " 5th. | Day. | 44 | 127,500 | 18,275 | | | | 129,800 | |
| " | " " | Night. | 50 | 144,500 | 15,700 | | | | 149,000 | |
| Saturday, | " 6th. | Day. | 31 | 66,300 | 12,250 | | | | 92,850 | |
| | | | 461 | 1,364,240 | 182,310 | 198,800 | 38,665 | 17,012 | 1,378,110 | 7 |

Total metal charged, . . 1,546,550 lbs.
Total steel produced, . . 1,378,110 lbs.

Loss in converting, . . 168,440 lbs. Per cent. loss, 11.

No. of blows made, . . 461
No. of bottoms used, . . 7 Average blows per bottom, $65\frac{4}{15}$.

As to the cost, the figures for the following statement are taken from Mr. H. W. Oliver's work during the past six months, although the production at present only averages a little over 100 tons per 24 hours. This is as much as the mill can take care of, but is not near the actual converting capacity, which should be with the two-ton vessels, about 150, and with the three-ton vessels about 225 tons per 24 hours.

*Summary of Cost Based on Bessemer Pig containing* 0.12 *Phosphorus.*

| | Total cost. | Per ton steel. |
|---|---|---|
| Pig metal as above, 609.04 tons, @ $18.00 | $10,962 72 | |
| Scrap " 81.34 " 15.00 | 1,220 10 | $19 80 |
| Coke " 96 65 " 2.00 | 193 30 | 0 32 |
| Limestone " 17.25 " 1.00 | 17 25 | 0 03 |
| Ferro " 7.60 " 72.50 | 551 00 | 0 90 |
| Fuel for steam and drying-bottoms, ladles, etc | 48 00 | 0 07 |
| Material for repairing bottoms, ladles, and cupolas (ganister and fireclay) | 115 30 | 0 09 |
| Maintenance of ingot moulds | 63 50 | 0 10 |
| Labor. Includes superintendence, chemists, maintenance of plant, and general repairs; also unloading all material, and delivery of ingots to rolling-mill | 968 70 | 1 57 |
| Total | $14,139 87 | $22 98 |

Steel produced, 615.23 gross tons. Average cost per ton, $22.98.
Per cent. of pig metal charged, . . . . . 88
Per cent. of scrap metal charged, . . . . . 11

Basing the cost of the above week's operations on pig metal, containing 0.3 phosphorus, which produces steel admirably adapted for nails, heavy hardware, tank-plates, sheets, etc., the results would be as follows:

| | |
|---|---|
| $1\frac{11}{100}$ tons pig metal at $15, . . . . . | $16.50 |
| Other items, as above, . . . . . | 3.08 |
| Cost of steel, per gross ton, . . . . . | $19.68 |

Of course, in a plant of the more modern type, improved machinery will cut down the labor required.

The figures given above I think convincing, and I have no hesitation in maintaining (and this year's work with the new plants will put it beyond the shadow of a doubt) that the total cost of conversion per ton is less than that of the most economical Bessemer works in this country, leaving entirely out of the question the interest on the original investment, which, of course, is heavily in favor of the Clapp-Griffiths.

Furthermore, the main question is not so much the cost as the quality; and we claim the special advantage that steel of a superior quality can be and is daily made from stock much of which would not be bought and could not be used by the most reckless Bessemer or open-hearth management. In other words, I firmly believe that pig-metal bought $3 per ton cheaper than the Bessemer, and put through the Clapp-Griffiths converter, can be made into steel and worked up into nails and many of the miscellaneous forms under which merchantable steel is sold in the United States to-day, with a large profit to the producer and perfect satisfaction to the consumer.

In support of this claim, Captain Hunt's expert testimony has already been given to the Institute. The convincing proofs of commercial experience are now accumulating. The letter of Mr. Henry McCormick of Harrisburg, contained in the paper of Captain Hunt, read at the Chattanooga Meeting (*Transactions*, vol. xiv., p. 142), speaks for itself. The short but entirely satisfactory experience of General Powell, at the Western Nail Company's works, Belleville, Ill., is another case in point. General Powell writes:

"Our new Clapp-Griffiths plant is developing a grand result, and our entire system is working up to our fullest expectations as to quality of steel ingots and plate, heating and rolling throughout. We are making a slab-ingot $50'' \times 14\frac{3}{4}'' \times 5\frac{1}{2}''$ and $5''$, weighing 1000 pounds, top-pouring. Ingot strips beautifully. The same is passed

through a 2½″ 3-grooved, 2-high train, which in three passes gives a long slab 15″ × 2⅝″, which is cut up into suitable sections for the various-sized nail-plate required.

"Steel rolling soft, edges of ingots and nail plate unsurpassed, nails A No. 1. We have moved out cautiously, using 75 per cent. No. 1 Bessemer and 25 per cent. Nos 2 and 3 mill-iron, running about 2 per cent. in silicon and .15 to .17 of phosphorus. Results very fine. Will go up in phosphorus slowly and cautiously."

For other commercial results reference may be made to the widely diversified character of the product of the Messrs. Oliver Brothers & Phillips mills, where this steel, high-phosphorus and low-phosphorus, is in daily use, and where, to the best of our knowledge, not a single ingot has ever been produced that could not be used.

The Spang Steel & Iron Company of this city writes as follows:

PITTSBURGH, January 16th, 1886.

MESSRS. OLIVER BROTHERS & PHILLIPS.

GENTLEMEN: We have received from you ingots which we have rolled down to wire-rod billets and disposed of as follows:

| | | |
|---|---|---|
| Ingots, . . . . . | | 5,134,820 lbs. |
| To Oliver & Roberts, wire-mill billets, . | 4,784,763 lbs. | |
| To Oliver Bros. & Phillips, crop ends, . | 227,381 " | |
| To Oliver Bros. & Phillips, defective billets, | 29,120 " | |
| Loss in heating and rolling, . . . | 93,556 " | |
| | | 5,134,820 lbs. |
| Percentage of loss in heating and rolling, . | | 1.8 |
| " " crop ends, . . . . | | 4.4 |
| " " defective billets, . | | 0.5 |

This showing, we believe, has never been equalled by any steel produced from any other process.

In conclusion I take, as my "profession of faith" in this process, the broad ground that the Clapp-Griffiths stands between the acid and basic Bessemer, and alongside and cheaper than the open hearth, for the production of soft steels of excellent quality from low-grade materials, with a smaller outlay for a plant, and less cost of conversion.

I wish it understood, however, that I do not assert that steel made from such low grades of iron is equal to that made from the best Bessemer stock; but when the best stock is used, I am informed that the steel produced has had for a year past a market value of from $2 to $3 per ton above Bessemer.

## Discussion.

Henry W. Oliver, Jr., Pittsburgh, Pa.: We have arranged to have all our thirteen trains of rolls running to-morrow on Clapp-Griffiths steel. The converting-house will be using Dunbar pig-iron with 0.25 to 0.30 phosphorus, and making a steel which we employ continually for heavy hardware, nail-plate, tank-steel, fish-bars, etc., and which stands much better tests than good bar-iron. In exploiting the line of using high-phosphorus pig there is no inducement in our market to go higher than 0.3, as an iron with that percentage of phosphorus can be bought at about the same price per ton as poorer grades. We are making three grades of steel: No. 1, from the lowest phosphorus pig-iron obtainable, for boiler-tubes, boiler-plates, car-links, rivets, etc.; No. 2, from ordinary Western Bessemer pig, 0.10 to 0.12 phosphorus, for wire-billets, sheet-bars, etc.; No. 3, from what is known in this section as good all-ore mill-pig, 0.25 to 0.30 phosphorus, for heavy hardware, lightning-rods, nail-plate, tank-plates, common sheet-bars, etc.

The greatest material and commercial advantage developed by the process so far, is the extension of the steel-limit for ores. We have shown the adaptability of 70 per cent. of the Lake Superior and Iron Mountain ores to the production of steel. It is impossible to overestimate the importance of that fact. I may instance the Vermillion district, which produces a non-Bessemer ore, that is, nevertheless, entirely suitable for the Clapp-Griffiths process; notably the Minnesota Mine, which produced 50,000 tons the year before last, and will produce 500,000 tons during the coming year. To this may be added the Chapin and other large producing mines in the Menominee range, the ores from which are mainly classed as strictly non-Bessemer, and are sold at 25 to 30 per cent. cheaper than the standard Bessemer ores of the Lake region. Only 15 to 20 per cent. of the product of the Lake Superior mines will make a standard 0.10 phosphorus Bessemer pig. No Bessemer or Siemens-Martin plant has continually made welding steel, though they occasionally make steel that will weld; but the Clapp-Griffiths converters, from the day they were started, made good welding steel, and nothing else; and we are using it every day for car links and chain, and supplying nearly all the manufacturers of boiler-tubes with welding-strips. This is a line which the Bessemer and Siemens-Martin people have, after repeated attempts, abandoned.

W. H. POWELL, Belleville, Ill.: I investigated thoroughly the Clapp-Griffiths process before contracting for a plant. We proceeded with its construction and made our first blow on January 21st. I was astonished at the results on the first day; they were far above my expectations. I had been led by the experience of the Bessemer men to look forward to a lively time for at least a month or two in getting things into proper shape to make good steel. Our plant worked smoothly from the first day. One of the points I had to consider was handling the steel in a way to obviate the building of a large and costly blooming train. Prior to building our Clapp-Griffiths plant we were using old iron rails, faggoting them in faggots 12 inches square, about 5½ feet long, and weighing about 1000 pounds, reducing them into a slab 12½ inches wide by 2½ inches thick, in three passes, in an ordinary slabbing muck-train. I thought that I could do about the same thing in steel, after witnessing the experiments of the Messrs. Oliver. I arranged to strip the ingots while hot, and, wash-heating them in a furnace I had constructed for that purpose, passed them through a slabbing-train with the same housings and driving-power I had for iron, with but 23½ inch rolls. The ingots were 14¾ inches wide, 5¼ inches thick, and 48 to 50 inches long. I reduced these ingots to 2⅜ inches thick in three passes, and I am doing so to-day very successfully. That slab is then cut up into sections for nail-plate and conveyed into another wash-heating furnace, and then rolled into nail-plate; so that to-day we are rolling steel from a 14⅜ × 5¼ inches by 1000 pounds ingots as light as No. 12 wire gauge, 15 inches wide, in 9 passes. If there is anything better than that in the United States I would like to hear of it.

Moreover, in this process, so far as nail-plate is concerned, we have done away with the necessity for an edging-groove. We do not edge our steel a particle, except that we roll in collared grooves. We cast our ingots 14¾ inches wide. The first pass in the slabbing-train is 15 inches, and the slab is all made in that first groove. In the two other passes in the slabbing-train and the four other passes in the nail-plate roughing-rolls, the grooves are exactly 15 inches, and the plate is not allowed to spread a particle. The result is that we have edges on our nail-plate that cannot be excelled by any method of rolling any other metal, no matter what it may be.

As to our mixtures, we have used No. 1 Bessemer and No. 1 and No. 2 mill-pig. We have made steel from No. 1 and No. 2 mill-iron (0.16 to 0.19 phosphorus) made from various Missouri ores, and

it has given us as good results in every particular as the steel made from No. 1 Bessemer. The plate and the nails, which I here exhibit, are made from mill-irons containing 0.14 to 0.19 phosphorus, made at Sligo Furnace and Midland Furnace, in Missouri, which irons, on account of their being unsuitable for Bessemer use, I bought for $2 per ton less than I paid for the regular Bessemer iron.

Before we started, it was said, we would only be able to make a soft nail, which would not drive into oak plank. In the block of seasoned oak, herewith shown, you will find, clinched, an 8d. casing nail that I bent flatways to a sharp angle in a vise, and then bent the point edgeways. I then drove the mate of it through that 2-inch oak plank, and clinched it on the other side. We have demonstrated that the heads will not fly off nails made of this metal, as they are said to do incessantly off those made of Bessemer steel. As you can imagine, I am more than satisfied with the process, and confident of its superiority to the Bessemer for the economical production of soft steel and of nails. We will go up in phosphorus slowly and carefully.

H. M. HOWE, Boston, Mass.: After much inquiry, I confess myself wholly unable to find out what the Clapp-Griffiths process is, and I come here to ask whether there really is such a thing as the Clapp-Griffiths process. I do not say that there is no such process, although I may say that the very great majority of the large number of persons I have consulted, who are in a position to form opinions of value in the premises, are unhesitatingly and unqualifiedly of the opinion that no evidence has yet been produced to warrant the belief that such a process exists. In saying this I must expressly state that I believe that the Clapp-Griffiths enterprise has directly and indirectly done a vast amount of good. Our steel manufacturers have had it brought home to them by the work done by Messrs. Oliver Brothers & Phillips, that, in a cheap, small plant, a large quantity of steel can be manufactured at reasonable cost, and of excellent quality. The community is under a debt of gratitude to the promoters of the enterprise. Still, this fact is in itself no evidence whatsoever that there is any Clapp-Griffiths process—that is, that the operation carried on in the Clapp-Griffiths converter differs, in kind, from that carried on in the ordinary Bessemer converter, to such an extent as to warrant us in speaking of that operation as the Clapp-Griffiths rather than as the Bessemer process. Would it not be far more reasonable to insist on calling the operation carried on in the ordinary Bessemer converter the Mushet process than to speak of that carried on in the Clapp-Griffiths converter as the Clapp-

Griffiths process? Let us remember that the prodigious advances, which the Bessemer process made, owing to Holley's brilliant inventions, never suggested such a thing as calling it the Holley process.

Among the original claims put forward for the Clapp-Griffiths enterprise were cheap installation and cheap working. Now, I understand that these claims have been withdrawn. What remains? The claim that, by removing the slag from the vessel, the reduction of silicon from that slag is prevented, and that, for this reason, or for some similar reason, the product approximates wrought-iron in its properties, and that the presence of a given amount of phosphorus is less productive of brittleness, both hot and cold, in steel produced in the Clapp-Griffiths than in that produced in the common converter. Now, I do not deny that this is true, but I do claim that it has not been proved to be true; that the evidence offered has been utterly insignificant and wholly insufficient. I further claim, that, until sufficient evidence has been offered to substantiate the claim that the Clapp-Griffiths converter removes silicon or neutralizes phosphorus or produces some similar effect to a greater degree than the common converter does, there is no justification whatsoever for speaking of the operation carried on in the Clapp-Griffiths vessel as the Clapp-Griffiths process. Until it has been proved to differ from the Bessemer process, it must be called the Bessemer process. Using a Holley crane or an Allis engine or a Worthington pump in the Bessemer process does not constitute a Holley process or an Allis or a Worthington process.

I do not wish to split hairs, least of all when bearding the lion in his den. But I think we owe it to ourselves and to the community to challenge the right of these gentlemen to speak in our *Transactions* of their operation as a new process, and to call upon them to produce their evidence; because, as I apprehend, calling it a process asserts by implication that it yields a product differing in some important way from that obtained under like conditions in the Bessemer converter. It is at present very difficult to compare the high-phosphorus product of the Clapp-Griffiths converter with similar products of the common converter, because no one about us, so far as I am aware, is making high-phosphorus steel in the common converter. But the burden of proof is on the promoters of the Clapp-Griffiths cause. Let them give us, not two or ten, but hundreds, of analyses of high-phosphorus steel, some made in the common converter and some in the Clapp-Griffiths. Let them at the same time give us the tensile strength and ductility-tests of

these steels, and let us see whether, when all other conditions are equal, the product of the Clapp-Griffiths vessel is superior to that of the common vessel.

Mr. Oliver stated that his competitors could only occasionally produce such steel, and that they made a great deal of bad steel, and that consumers could not use it. I think Mr. Oliver is misinformed as to the quality and uniformity of the steel produced by his competitors. There are two Bessemer works to my personal knowledge, and others of which I have credible information, which are producing steel of the same tenor in carbon as that produced by him, with as great uniformity, as I learn from their written statements, giving the carbon in many successive heats, and (as I infer from personal examination of the steel in course of treatment, though I attach little importance to my own observations in this regard, as they do not cover sufficient length of time) with no greater proportion of cracked blooms and ingots. I attach great importance to the statements of several consumers of the product of these works, and of that of the Clapp-Griffiths plant, who inform me that they can distinguish no difference in the behavior of the two, either as regards ductility or welding or otherwise. The managers of the works I refer to are not broken down with care and overwork; they meet you smilingly; their works run on with commendable smoothness and ease. Against such testimony, is it enough to be told that the Clapp-Griffiths metal is better in ways in which its superiority cannot be reduced to tangible and directly comparable results nor expressed in figures? This would be unfortunate, for such claims are as difficult to disprove as they are to substantiate.

R. W. Raymond, New York City: While I do not care (and presume Mr. Howe does not care) much for names, I sympathize with him in the desire for more precise information as to the characteristics which entitle the use of the Clapp-Griffiths plant, as so greatly improved by Mr. Witherow, to be distinguished from the Bessemer process, and more satisfactory proof that the same results cannot be attained in the tilting converter. It is not surprising, and no one is to blame, that the evidence is still incomplete; nevertheless, we cannot deny that such is the fact. As to the possibility of obtaining with uniformity from existing Bessemer works a low-silicon steel, I can only give the following contribution to the discussion: We purchased last summer, and used with complete satisfaction as a material for wire, at the works of the Trenton Iron Co., a lot of Clapp-Griffiths metal. We also bought and used for the same pur-

pose, with equal satisfaction, a lot of Bessemer steel from Bethlehem. To satisfy our curiosity, we obtained the analyses of fifteen blows of this Bessemer lot. They showed great uniformity of chemical constitution, as the following table proves.

*Analyses of Soft Bessemer Steel, Made at Bethlehem, Pa.*

| No. of blow. | C. | Mn. | Si. | P. | S. |
|---|---|---|---|---|---|
| 625 | .097 | .43 | .014 | .047 | .084 |
| 628 | .092 | .48 | .019 | .056 | .070 |
| 631 | .093 | .47 | .017 | .043 | .080 |
| 634 | .097 | .51 | .017 | .044 | .051 |
| 639 | .094 | .44 | .012 | .044 | .055 |
| 641 | .090 | .34 | .017 | .047 | .069 |
| 648 | .096 | .42 | .021 | .047 | .058 |
| 650 | .094 | .49 | .018 | .063 | .050 |
| 655 | .085 | .40 | .012 | .046 | .072 |
| 658 | .088 | .41 | .014 | .045 | .060 |
| 660 | .088 | .39 | .016 | .045 | .068 |
| 664 | .087 | .42 | .016 | ... | .057 |
| 667 | .086 | .39 | .017 | .047 | .058 |
| 670 | .087 | .36 | .017 | .043 | .065 |
| 673 | .090 | .46 | .015 | .053 | .076 |

I cannot personally vouch that this metal welded well; but it was reported to me at the time that such was the case. At this time, it is impossible for me to verify that report.

In this connection I will submit also some analyses of soft Bessemer steel made about June 1st, 1885, for a large consumer: the first is Bethlehem steel, the other four are German.

*Analyses of Soft Bessemer Steel.*

| | I. | II. | III. | IV. | V. |
|---|---|---|---|---|---|
| Phosphorus, | .058 | .063 | .079 | .087 | .074 |
| Sulphur, | .113 | .033 | .036 | .06 | .031 |
| Silicon, | .002 | .007 | .005 | .009 | .009 |
| Manganese, | .792 | .46 | .53 | .40 | .44 |
| Carbon, | .164 | .07 | .06 | .06 | .06 |

I believe that low-silicon steel has been made in large quantities at Seraing.

R. W. HUNT, Troy N. Y.: In view of the character of this discussion, it seems to me proper that I should refer to my personal connection with the Clapp-Griffiths *manner* of making steel—certainly that term cannot be objected to by any one. As may be remembered by the Institute, when I first visited the Messrs. Oliver's works I was unfavorably impressed, and advised them to go slow in spending any more money on their experiment. But further investigation

and observation convinced me that it possessed much greater claims for serious attention, and, later, my experiments, the results of which I have had the honor to present to the Institute, fully satisfied me that in the Clapp-Griffiths converter better and more uniform low-carbon metal could be produced than in the regular Bessemer practice—of course basing this opinion on my individual experience. If others have been more successful in keeping Bessemer steel absolutely uniform, I can only congratulate them. As perhaps is quite well known, we make at Troy fully as great a variety of grades of Bessemer as any works in this country; and, while not wishing to "talk shop," I must say we are pretty well satisfied with our reputation for spring-steel, gun-barrels, gun-frames, drop-forging, dead-soft, axle, machinery, and a lot of other kinds of steel. But I know that in the matter of silicon, for instance, we have varying results. In the Clapp-Griffiths metal, I have always found almost absolute uniformity. Mr. Howe states that the first two great claims advanced by the Clapp-Griffiths people were cheapness of installation and low cost of product, and that both of these claims have been abandoned. So far as I am concerned, I most emphatically deny this. When I stated that from 100 to 125 tons of ingots per day could be regularly made in the Oliver plant, I was laughed at, and many of my friends told me good naturedly that I had made a mistake. The result has proved that I understated their capacity. The more complete plants of General Powell and others will do better. Now, I want to see a regular Bessemer plant put up at a cost of not over $50,000, which will do as much. As to cost of production, Mr. Oliver has permitted Mr. Witherow to give you an absolute transcript from his books. If they do not compare favorably with those of the largest Bessemer plant, let us have the figures to prove it. Perhaps I am also badly informed on this point.

I do not care a penny whether this Clapp-Griffiths business is a "process" or not. If, as has been stated to you, it permits the successful using of the cheaper non-Bessemer ores, and so helps to enrich our country, it can afford to go without a name. If the Bessemer people can use the iron made from these ores, and which they can buy for several dollars less per ton than standard Bessemer pig, why have they not been so doing? Three dollars per ton would seem to be worth saving.

Since making the experiments with the Clapp-Griffiths converter which I contributed to the Institute, I have had neither time nor opportunity to continue them; and, in fact, I have felt content to

await the results obtained in the several plants being built, feeling certain I would be fully sustained in all I have asserted. Part of that vindication has been offered to-day by General Powell. As to the results obtained by Dr. Raymond from Bethlehem steel, I must say that I know those works make good steel, but would also ask if Dr. Raymond knows the history of Bethlehem's regular running. If our steel varies, we are not compelled to use it all for one purpose. What I claim is that, based on my experience, there is less variation in the Clapp-Griffiths converter than in the Bessemer. I have never yet seen a heat spoiled in the former. Now, as to what causes the peculiar merits of the Clapp-Griffiths metal, I do not know. In my paper I asked if it might not be the uniformly low silicon. It may be something else. But I am convinced the merit is there. It remains for the chemists to determine the reason for it.

MR. HOWE: I think that Captain Hunt misunderstands me. There is, perhaps, no one to whose *ipse dixit* as to the quality of steel I would bow more deferentially than to that of Captain Hunt, for whose opinion in such matters we must all have the deepest consideration. But it is not desirable that in such a case we should simply rely on the *ipse dixit* of any man. What we want is not mere assertions backed with at most a trifling amount of evidence, but we want the evidence ourselves in detail, and plenty of it; for in such a case there should be no difficulty in producing and explaining the evidence. As to the cost of installation, I am surprised at what Captain Hunt says. I understand that the essence of the Clapp-Griffiths plant is the slag-spout for running off slag during the blow, which may or may not be combined with horizontal tuyeres. About this I do not speak with positiveness, as my efforts to find out just what Clapp-Griffiths does consist in, though made with some care and patience, have thus far been somewhat unsuccessful, and I would thank the eminent gentlemen present who are promoting the cause to enlighten us.

It is true that the Clapp-Griffiths vessels are actually stationary, and a stationary vessel saves the cost of a hydraulic cylinder, rack, and trunnions for rotating, and that the tuyeres are situated some distance above the bottom of the bath of metal, thus permitting the use of somewhat lighter blast, and hence, of cheaper engines and boilers; but, in the first place, these savings in cost are not serious, and, in the second place, they are not due to Clapp-Griffiths. When I say that I do not see how a Clapp-Griffiths plant is to be much cheaper than a Bessemer plant, I do not mean to compare a 2-ton

Clapp-Griffiths plant with a 10-ton Bessemer plant. But I wish to compare the Clapp-Griffiths plant with a Bessemer plant of the same size, and as nearly as possible resembling it, without having the essential points of the Clapp-Griffiths design. Horizontal tuyeres some distance above the bottom can hardly be claimed as Clapp-Griffiths and non-Bessemer, because they were employed, as I understand, long before Clapp-Griffiths rose above the metallurgical horizon; nor for the same reason can stationary converters be so claimed. Will Captain Hunt inform us how the attachment of a slag-runner to a vessel is going to materially alter the cost of installation? Or, if I am wrong (and I profess to be in darkness as to this matter), will he kindly inform us wherein the difference lies between the cost of installation of a given Clapp-Griffiths plant on the one hand, and that of a Bessemer plant, differing from it only in those features which are the essence of Clapp-Griffiths, on the other hand?

Finally, as to silicon I am more in the dark than as to anything else. The advocates of the Clapp-Griffiths cause tell us that in their vessel silicon is eliminated more completely than in the common vessel. I take their figures showing the progress of the removal of silicon during the blow, and I plot from them a curve. I plot similar curves showing the rate of removal of silicon in the common vessel; and I completely fail to find any indication whatsoever that this element disappears more rapidly in one vessel than in the other. I next inquire among the Bessemer works which are making steel containing the same amount of carbon as that made in the present Clapp-Griffiths practice. I am informed by gentlemen in whose statements we all place the most complete confidence, whose veracity we cannot for an instant question—whose names I will communicate to Captain Hunt if he desires, but not to this meeting, as the information was given me somewhat confidentially—I am informed by these gentlemen that, when the carbon in their steel is 0.10 per cent. or less, their silicon is below 0.01 per cent.; and when their carbon runs from 0.10 to 0.15 per cent. the silicon is always below 0.015 per cent. At these works the average carbon is not over 0.13 per cent., and they inform me that they have never found over 0.015 per cent. silicon in steel carrying 0.10 per cent. or less of carbon; *never*—this is absolutely unqualified—and in such steel the silicon only rises as high as 0.015 per cent. in exceptional cases. Now, if the common vessel takes out practically all the silicon, how can the Clapp-Griffiths vessel take out more than all? Will the gentlemen

kindly lead us out of this perplexing dilemma and show us where the advantage of the Clapp-Griffiths vessel does lie as regards the removal of silicon? Will they demonstrate to us that 0.01 per cent. of silicon has any appreciable effect in steel designed for purposes for which the products of the Clapp-Griffiths and the Bessemer converter are employed?

MR. OLIVER: In regard to the point that Mr. Howe raises I do not doubt that there are some concerns (and I know the company to which he alludes), that by continual watching and incessant effort do get a good soft steel; but they have to be continually on the watch; with them it is a struggle, it is an effort, to reach the point he has named. With our plan of putting up a mill and making steel we obtain these results in a natural easy method, without this constant effort; we make good soft steel all the time. I would suggest that the difference between the old Bessemer method and ours is somewhat similar to that between puddling iron and boiling iron. To my mind there is just as great a degree of difference. The proper way is to boil the iron.

It has been suggested here that a small Bessemer converter might be used. Now let me suggest that we have advanced from the small Bessemer converter; that the converters in England, and many of them in Germany, are still small converters.

It is objected that this is not a process. Now, what is the meaning of the word "process"? Is it not advance and progress; does it not mean to proceed? Did we not advance and progress by making a stationary converter and using this our method of "boiling" this material? There is something in this process. I cannot tell you what, only I appeal to you to say whether if we produce continually better material we are not entitled to tack to the end of it the name "process"? I claim that any concern that has a reputation for making soft steel by the old Bessemer process at times takes up from twenty-five to thirty minutes, tilting the converter backward and forward, and does it as you would a sick child, to bring the steel up to the proper point; and even then there are only one or two concerns in the country that are making soft steel. We do not say you cannot make good soft steel by the regular Bessemer process, but we do say that you *do* not do it continuously by that process, as we do by ours.

During the past ten years, I have been, I think, the buyer of a larger quantity of Bessemer material than any of my neighbors, running from a few thousand tons in 1876 and 1877 continuously

up until it was as high as 25,000 or 30,000 tons a year. I bought from nearly every maker; bought from all over the world. I visited the other side once or twice to find the best maker, so important was the matter to us. I say to you that lack of uniformity was the name of Bessemer steel. The best makers here change in a day, and drop off suddenly without any reason. We have a rod-mill below us and are buying for it 4-inch billets from three or four different makers. We are selling our own make of billets to pretty nearly every concern around us. We are getting from $3 to $5 and $6 a ton more for the same identical size of billet than those we buy; we are getting that much more money from our neighbors for our billets and buying other billets for our rod-mill at that much less. We are selling our billets at $36, where the market price of Bessemer billets has been $31 a ton. Now, is it because these people are taken with this method that they come in and pay us $3, $4, and $5 a ton more for material? I hope, gentlemen, you will allow us to have that little name, "process." We worked a couple of years pretty hard for it, and have done something that other people did not do before, and we would like to have that name.

MR. RAYMOND: I desire to add a frank and friendly word. The most important questions that come before us in a technical way are very likely to be questions in which some of us have a business interest. I can only hope that they will always be discussed with the politeness and good nature that have been shown on this occasion. Business interests are, of course, not regarded in such discussions, and when gentlemen submit for our rigid cross-examination and technical criticism propositions in metallurgy or chemistry or engineering, they will not consider themselves attacked when their propositions are attacked.

As for the claim of absolutely uniform good results, I make bold to say that it belongs to the infancy of a new method. When the Clapp-Griffiths works shall have grown to be as numerous as I should be glad to see them, and the product is more abundant than now, it is safe to prophesy that somebody, at some time, somewhere, will make bad heats in the Clapp-Griffiths converter. But I do not at all question the statements here made of a great practical success in the manufacture carried on by our Pittsburgh friends; and in joining with Mr. Howe to doubt (not deny) the essential novelty of their product or their method, I am as ready as I know he is, to accord to them full credit for their enterprise and skill.

WILLIAM GARRETT, Pittsburgh, Pa.: I understand very little

chemistry; but speaking as a practical man, accustomed to the manipulation of various irons and steels, I must candidly say that there is something very peculiar indeed in the product of the Clapp-Griffiths process.

J. D. WEEKS, Pittsburgh, Pa. (in reply to a remark from Mr. Jacob Reese, of Pittsburgh): I have steel in my possession that contains more than 1.5 per cent. of silicon and welds perfectly.

C. B. DUDLEY, Altoona, Pa.: The chemistry of iron and steel can only be said to be thoroughly understood when three things are known: 1. The number and kind of chemical elements present. 2. The amounts of each of these different elements. 3. The way in which these elements are combined with each other. Most of the chemical work hitherto done on iron and steel has shown only the first two of these requisites. We know what chemical elements are present, and the total amounts of them; but we do not know what combinations of these elements—in short, what chemical compounds —are present. I offer simply a suggestion that the difference between the soft steel made in the Bessemer converter and that made in the Clapp-Griffiths process, especially as to its behavior in rolling, may be due to a difference in the condition of the phosphorus in the two metals. It is generally believed that in Bessemer steel the phosphorus exists as phosphide of iron; and indeed it is claimed by many chemical metallurgists that in the ordinary acid Bessemer process this is practically the only form in which the phosphorus can exist. The phosphide of iron is believed to be a highly-crystallized body disseminated through the mass of metal and interfering with its continuity. In the Clapp-Griffiths process, on the other hand, it is possible—and many of the conditions and circumstances in carrying out this process seem to favor this view—that the phosphorus may exist in the form of phosphate of iron, or the phosphide may have been oxidized. This phosphate of iron is believed to be a common constituent of wrought-iron, and, in fact, may be regarded as a species of slag disseminated through the metal. It is almost universally believed, I think, that phosphorus is a much less objectionable constitutent of wrought-iron than of steel; and, as I have said, I simply offer the suggestion that this may be due to the condition in which the phosphorus exists, and that this same explanation may account for the remarkable difference said to manifest itself in the behavior both during manufacture and in the metal during the subsequent working.

S. A. FORD, Braddock, Pa.: Dr. Dudley's remarks on certain

probable combination of the metalloids and the metals in pig irons and steels recall very forcibly to my mind some experiments which I made some seven or eight years ago on the chilling properties of cold-blast irons and the wearing properties of chilled cast-iron car-wheels. At that time I was chemist of a large car-wheel foundry, and we were endeavoring to discover why one iron would give a good, hard chill, and yet in another iron, although chilling, the chill would be soft and good for nothing; and furthermore, why one wheel would make a mileage of 10,000 miles, and yet another 100,000 miles. During my experiments I found that two elements played the most important part in the chilling of irons and in the wearing property of chilled wheels, namely, silicon and carbon; consequently, I watched the action of these two elements more closely than any of the others. It was my good fortune to obtain a number of old car-wheels which had records of different mileage. I obtained one which had only made 10,000 miles, and others that had made their 40,000, 50,000, 60,000, 70,000, and two that had made over 100,000 miles. The wheel that gave the least service and the wheel that gave the largest amount of service were found to contain almost identically the same amounts of both silicon and carbon.

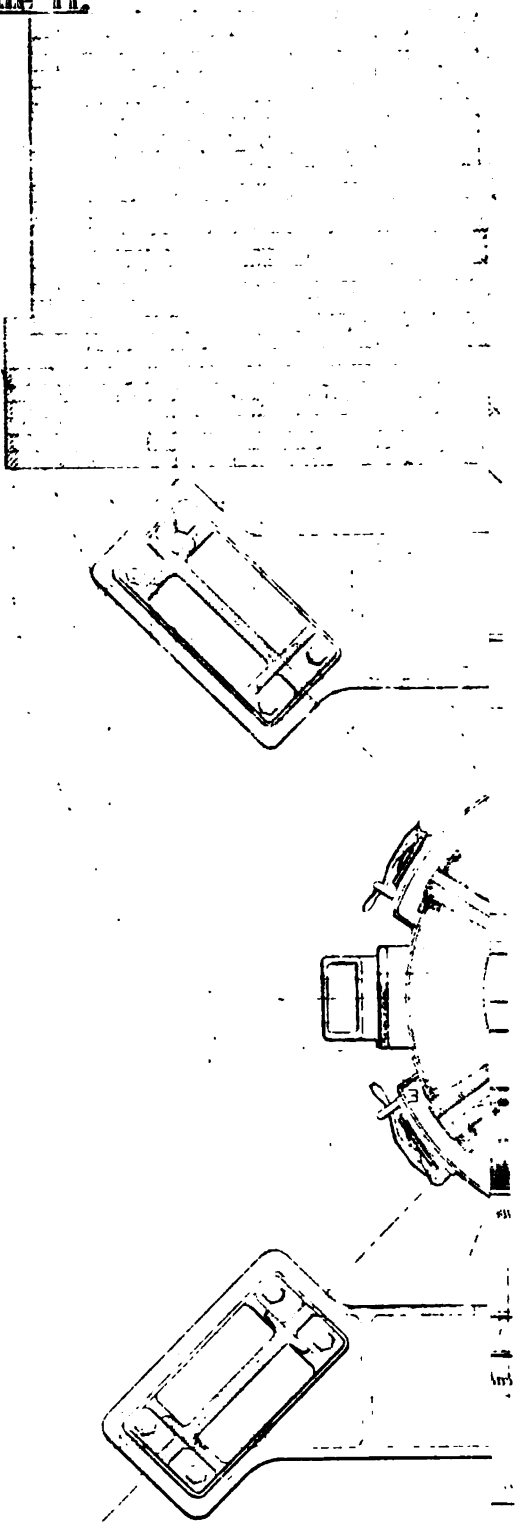
It was in the chills of these two wheels that I discovered what I am convinced is a combination of silicon with carbon, and this combination of silicon and carbon was greater in the wheel that had made the longest mileage. This fact I also found whenever I tested a wheel that had made good service; this peculiar combination was always present in large quantities. As to how to obtain this silicon, the best way I found was to crush the chilled iron as fine as possible, dissolve in hydrochloric acid of 1.06 specific gravity, and during solution pass a stream of carbonic-acid gas through the flask to prevent oxidation. After boiling for about an hour, the iron having been dissolved, there will be seen in the flask all through the solution small particles which would be taken for flocculent silicon, but of a slightly yellowish color. On filtering this solution and washing this apparent flocculent silicon with hydrochloric acid to get rid of the iron, and then pouring on the filter a hot potash solution of the strength of 1.25 specific gravity, there will now be observed to be a strong effervescence and hydrogen will be given off in large quantities. This apparent silicon will be dissolved and pass through the filter in solution with the potash; in the filter will remain a black mass which resembles black varnish more than any-

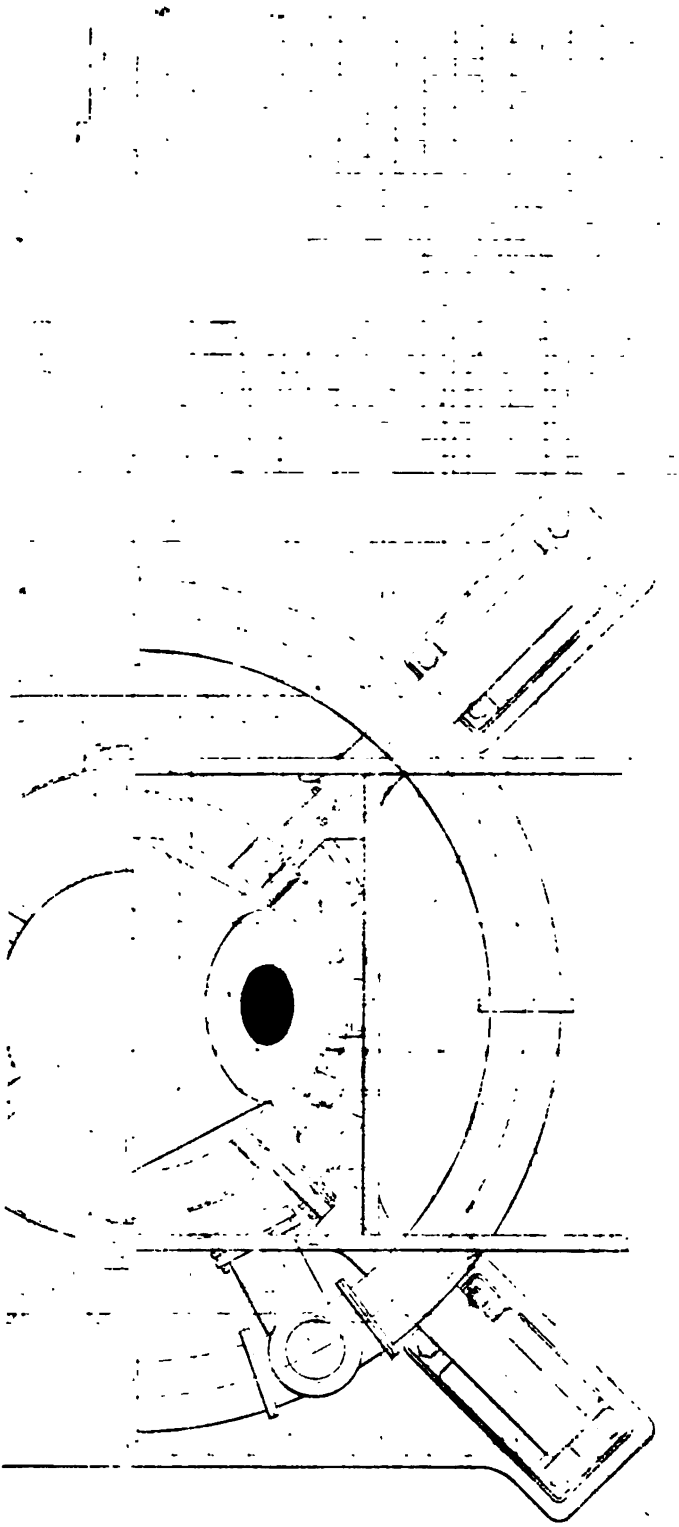
thing else I can compare it to. Now these facts were not once obtained but repeatedly, and I always found that those wheels that had made the largest mileage invariably contained a large amount of this form of silicon, while those wheels that had made a small mileage contained very small quantities of this same silicon.

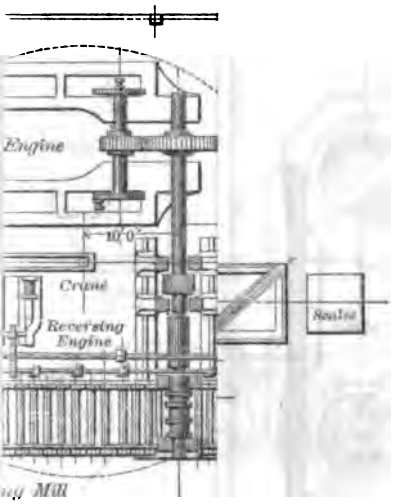
Further, wishing to use some cheaper irons than the coal-blast charcoal irons, and at the same time irons that would give as good wearing chill as the cold-blast irons, I, through the kindness of Captain Jones, of the Edgar Thomson Steel Works, was allowed to take tests of the heats in the Bessemer converter at different stages of the blow.

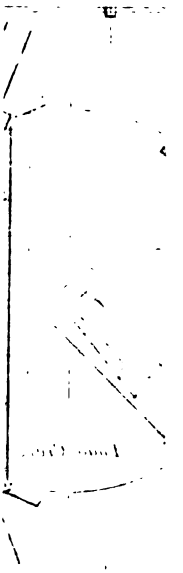
My first test was made of the cupola-iron as it ran into the converter. I then blew the heat about three and a half minutes, turned down and took a small test. This test on being broken open was found to be fair gray iron. These two irons, the test of the cupola-iron and the iron that had been blown three and a half minutes, were the next day melted in crucibles, and we made what are known as "chill-tests" of them. That is, a small mould was made with three sides of sand and the fourth side of iron. The test-pieces were about six inches long and about two inches by half an inch. On breaking these tests the cupola-metal was not chilled at all, while the partially Bessemerized metal was found to be chilled for over an inch in depth. On testing this chill I found that it contained this peculiar form of silicon in large quantities. We, therefore, determined to make car-wheels of this partially Bessemerized metal and see how they would wear. We made the wheels and put them into service. The last that I heard of them was about two years ago, when they had made their 250,000 miles, and the report was that they were not worn out yet.

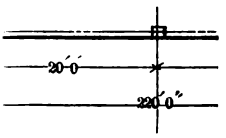
Now I think from this report of the good service of these wheels that it certainly shows that this insoluble form of silicon plays a very important part in the wearing properties of chilled car-wheels. Another very curious fact, which seem to show that the carbon exists in these chilling irons in some different form than in which it exists in the hot-blast or non-chilling irons, can be proved by dissolving some of the boring of a chilling iron in strong hydrochloric acid, evaporating to dryness and heating until the chloride of iron is all decomposed, then redissolving in hydrochloric acid, filtering and washing the residue free from iron. Now if we pour on the filter a hot solution of potash of the same strength as before mentioned, viz., 1.25 specific gravity, we shall obtain a filtrate which

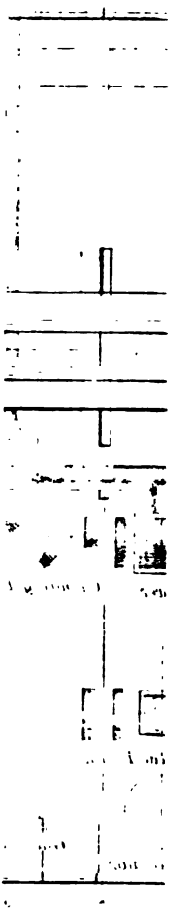


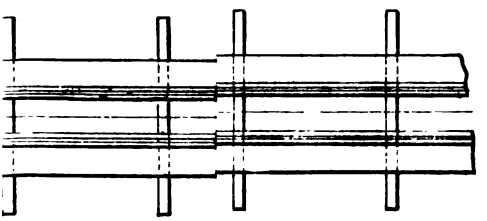



Engine
10'0"
Crane
Reversing Engine
Scales




20'0"
22'0"





14678

will be colored according to the depth of the chill which the iron will take if it be melted and poured against a chilling surface. The deeper the color the greater the chill. By this test I was able to predict, before an iron was used, how deep a chill it would give. I think this certainly proves that silicon and carbon do exist in forms which exert great influence on certain properties of cast-iron, and, if they do in pig-iron, why should they not in steel?

F. FIRMSTONE, Easton, Pa. (Communication to the Secretary): When vol. xiii. of the *Transactions* was printed, I was not able to refer to my authority for the statements I made at the New York meeting in February, 1885, as to the early history of the Bessemer process (*Transactions*, vol. xiii., p. 770). I have since found it in *Jour. Iron and Steel Inst.*, 1880, ii., p. 573.

This does not quite bear out what I said, viz.: that the first blow gave good material which could not be reproduced in subsequent trials. It merely stated that two bars about 25 feet long were rolled from this first blow, but that the process was afterwards given up, "the results being quite unreliable."

On page 574 Mr. Edward Williams further says: "Some months afterwards, Mr. Bessemer sent some ingots, from which perfectly sound rails were rolled. These rails contained 0.4 per cent. of phosphorus."

---

## *THE HEINE SAFETY-BOILER.*

BY E. D. MEIER, C.E., ST. LOUIS, MO.

SINCE Dr. St. Albans, in 1840, began to build successful water-tube boilers—some of which are still in use—the gravity-return water-tube boiler has been built in many forms, more or less familiar to all who have studied the subject. A single firm in this country published recently a pamphlet, showing some fourteen modifications of their boiler during about as many years. There were hence available to the thoughtful inventor of this latest form many data showing what forms were to be avoided, as well as the effects sure to follow certain erroneous methods of construction in the older types. Improvements in materials, tools, and workmanship made possible, forms formerly prohibited by excessive cost.

The first Heine boiler was built by A. Borsig & Co., for the

Berlin Exposition of 1879, and has since continued in uninterrupted service, without repairs of any kind, and with a working pressure of 150 pounds per square inch. A number of modifications were suggested to Mr. Heine by the writer, and have, after due practical test, been embodied in the later patents, so that the boilers, as now built in America, are practically of the type fixed for the first one built by me in St. Louis, in October, 1882.

The accompanying illustration shows the Heine boiler, which consists in the main of one or more inclined cylindrical shells *B*, with ample water-legs *C*, riveted to the same near the ends, and a series of tubes *T*, in staggered rows, extending from the inner sheet of one leg to the same sheet of the other, being rolled into them by Dudgeon expanders.

These water-legs take the place of the headers in sectional water-tube boilers, and, dispensing with unreliable castings, are made entirely of best homogeneous flange-steel, and stayed by hollow hydraulic tubing of large diameter. This ensures the greatest possible strength and durability, since all tests of stayed surfaces have shown the shearing strength of the thread on bolts or in the sheet to be the vital point of the structure. In these stay-bolts, the shearing area of the threads is about double that of the average stay-bolt sanctioned by marine and locomotive practice.

Further essential parts are the internal submerged mud-drum *D*, one for each shell; feed-pipe *F*, and blow-off *N*; the deflection-plate *L*, over the forward throat, and the dry-pipe or dry-pan *A*, the hand-holes plates *H*, and the hollow stay-bolts *O*.

The vital improvements in the Heine system over the older forms of its type are:

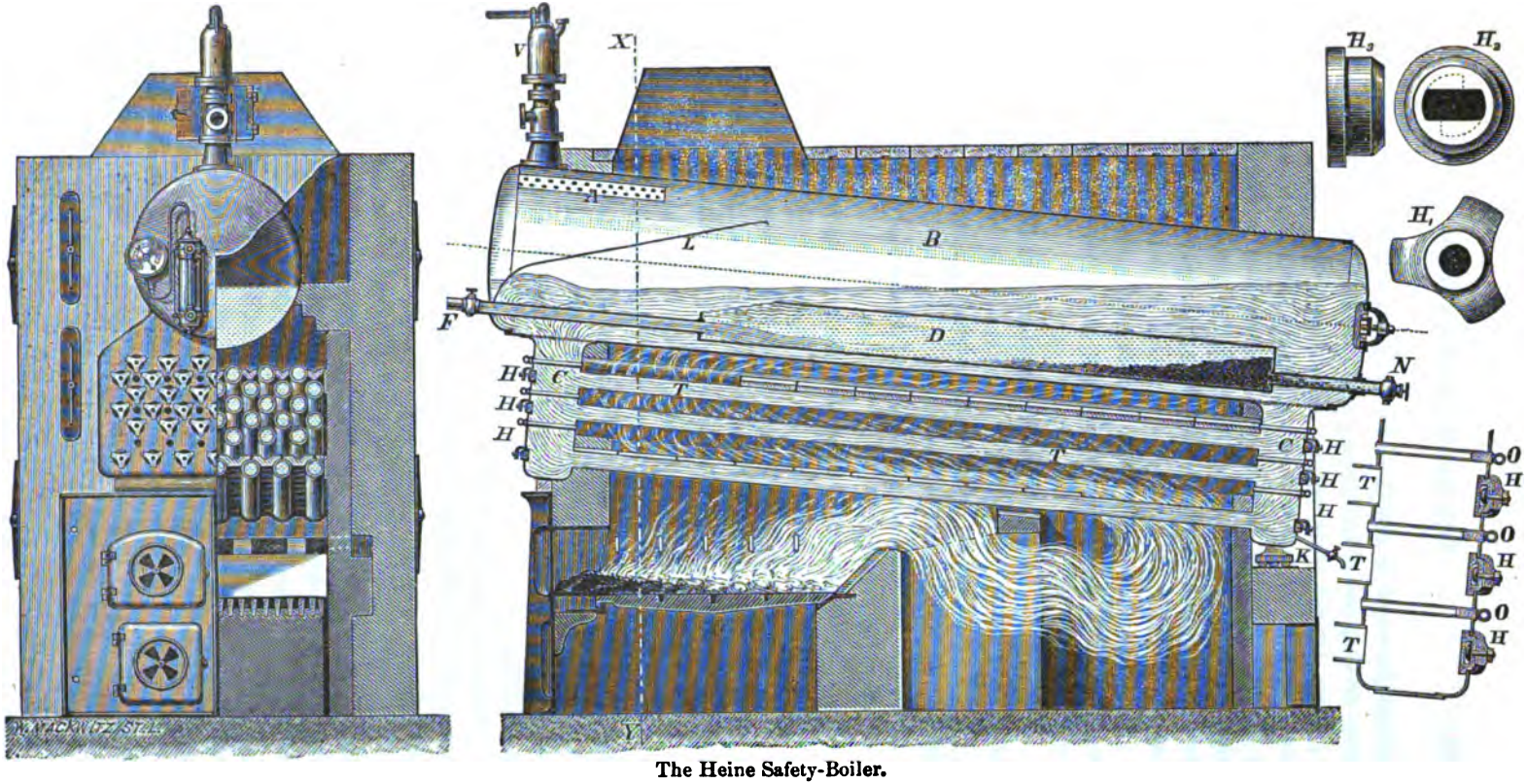
*First.* Unobstructed circulation of the water, by reason of the ample throat-areas, which permit perfect gravity-return at the rear end under all conditions of forced service.

*Second.* Horizontal or gradually ascending travel of the gases controlled by light fire-brick tiles or cast-iron troughs placed in the tubes.

*Third.* The availability of a large combustion-chamber at a point where the gases are hottest, thus completing the combustion of the fuel before cooling, by coming in contact with the principal heating-surface.

*Fourth.* Removal of all riveted joints from direct contact with the flames, which make two complete turns before reaching the shell.

*Fifth.* Gradual reduction of velocity of circulation from the point




**The Heine Safety-Boiler.**

where the steam is generated to the point where it leaves the water, thus making the evaporating-surface more effective.

*Sixth.* Larger steam-space in front near the steam-outlet; more water in the rear, where it is wanted for gravity-return.

*Seventh.* Gradual heating of the feed-water in the mud-drum to the normal temperature of the boiler, thus insuring equality of temperature and consequent diminution of expansion-strains throughout the boiler.

*Eighth.* An internal receptacle of practically still water, inviting the deposit of mud and loose scales at a point where they can be readily blown off.

*Ninth.* Inside joints of hand-holes closing to the pressure (instead of against it).

*Tenth.* Blow-off for soot and ashes provided without the necessity for doors on sides or top of walls.

*Eleventh.* General compactness and accessibility of all parts for inspection from without.

These points result from the skilful arrangement of the details as follows:

The inclination of the tubes, combined with the gradually ascending travel of the gases, will induce circulation of a certain velocity; and in the Heine boiler this speed is not checked by contraction of area, as in the older types, but is left to decrease naturally, as it finds larger channels, and as the impelling steam separates from the water. Hence the circulation will be of greatest velocity in the tubes, preventing the settling of sediment or scale, while in the older types the speed is greatest at the point of delivery into the main drum.

This is so marked, that in using water containing quantities of lime salts, the tubes are found to be cleaner the harder the boiler is pushed.

The main body of the water being found at the rear end of the shell, it falls naturally into the rear water-leg without contraction or eddying, the space at the throat presenting an area equivalent to the aggregate cross-section of the tubes to be supplied.

Combining this fact with the second and third points above mentioned, which cover the gradual ascent of the burning gases from a large combustion-chamber, we see the reason for the great capacity of this boiler for evaporation. A temperature of about 2200° F. (sufficient to melt cast-iron) has been observed between the lower row of tubes at the rear end, which had diminished to 1300° at the

top row, and to 840° at the forward end, where, however, but 30° difference was noted between the lower and upper row of tubes, further reduced to 600° or less on the last turn, leaving but 400°, on an average, to escape into the stack.

The difficulty and undesirability of drawing flame downward, against its natural tendency, is entirely avoided by the Heine setting; and an unmolested view of the outside of the tubes—while in service—is afforded through the hollow stay-bolts. Through these the eye can detect, and the pyrometer verify, the gradual absorption of the heat by the clean and constantly water-swept surface of the tubes.

With all fuels in common use, the advantage of an ample combustion-chamber in which expansion and intermixture will induce perfect combustion, is incalculable. The deposit of ashes and cinder, lime, etc., formed in blast-furnace gases, is also more readily accomplished in a deep combustion-chamber, like the one shown, *before* passing the gases around the tubes for their final work. Smoke, which is but unconsumed fuel, is most easily prevented or reduced when space, time, and heat, for complete combustion, are given before attempting to utilize the heat of the process.

The turning of the gases, when at their hottest, in spaces limited entirely by tubes filled with running water, facilitates the absorption of their heat, and leaves them cooled sufficiently to pass rivet-joints without injury, even when bad water is used.

The circulation of the water being gradually reduced in speed, *after* leaving the tubes, facilitates the elimination of the steam, while the surface of evaporation, being a moving one, is increased in effectiveness. To any one who has observed the gradual growth of steam bubbles by absorption and accretion, in a flask or test-tube in laboratory practice, the statement is its own explanation.

The use and benefit of the larger water space in the rear has already been explained. The steam-outlet being placed in an enlarged steam-space, remote from the water-level, and the tendency of the water being to move away from it, insures that dryness of steam which is reported by steam-users as one of the prime advantages of this boiler. This is not to be underestimated in these days of compounding and condensing and of quick-speed engines.

Feed-water from the best of closed heaters comes into the boiler at a temperature a trifle under 212° F., and it is to be brought to 340° F. before it will give us steam at 100-pounds pressure. Admit it to a boiler in the ordinary way, and it will drop like lead to the

lowest point. Many a "mysterious" explosion has followed the sudden action of a previously idle feed-pump. And feeding into a lower mud-drum, with its attendant evils of "steam on top, water in the middle, and ice at the bottom," has been relegated into barbarous practice. In the case of the submerged and inclined mud-drum of the Heine boiler, this tendency of cooler feed-water is utilized in carrying the gradually precipitating lime salts, and the moving disintegrated scales to the *lower* (by 10 or 12 inches) end of the mud-drum, while the upper strata of water in the same drum, moving slowly to the top and front, become heated to nearly the normal temperature of the boiler before joining in the circulation.

The tubes exposed to the hottest flame being thin, and cooled by constant and rapid circulation, the shell and tube-sheets being thicker, less exposed to direct action of the fire, and cooled by slower circulation, a more equable temperature of the various parts of the metallic structure is the result, and hence, the unknown quantity of expansion-strains is practically eliminated.

As to the eighth point: Mud and crushed scales are, in practice, daily blown from the rear ends of the mud-drums of Heine boilers; and a record of a nineteen months' continuous run on Mississippi water, and of a fifteen months' run on Lake Michigan water, without cleaning, only corroborate the average observations of steam-users as to this claim.

The humanity of the ninth and economy of the tenth points follow from their simple statement.

As to the eleventh, its importance is found in the facility of transportation, of handling and of erecting these boilers. A 250-horse-power Heine boiler, weighing 11 tons, was recently shipped intact by rail to a distant point, and then transported by wagon to the boiler-house; the unloading and placing in position on fire-front ready for brickwork, was accomplished in less than twenty hours, by one mechanic and three unskilled laborers, who had never seen such a boiler before, and were entirely unfamiliar with the work.

The further fact that every internal part of the Heine boiler can be thoroughly inspected from without by the responsible engineer or owner, will be a great recommendation to men who have been obliged to rely for their information on the colored gentleman who takes his nap between the warm flues while "cleaning the boiler."

For blast-furnace or producer-gases, for the waste gases from puddling- or heating-furnaces, this boiler and its setting are recommended. It may be placed in the same relative position as the

ordinary flue or tubular boiler, though occupying much less space, and then gives us a combustion-chamber *under* the tubes, of 14′ to 16′ in length by any desired height, and a calorimeter area of any reasonable dimensions, considerably larger than the available or necessary stack area, thus fulfilling the conditions of thorough mixture and slow travel so necessary to complete utilization of the heating power of these fuels, while utilizing the supporting structures and chimneys already in place.

Forms of furnaces with deflecting arches of fire-brick are more readily applicable to this boiler than to ordinary shell-boilers, since no portion of its heating surface would be hidden by such arches.

The want of durability of such arches, owing to fluxing of the brick with the cinder and floating ashes of the burning gases, has led the writer to rely mainly on the T-tiles, which project through between the supporting tubes, thus forming a fire-brick chamber with only enough water-tubing to prevent the roof from falling. These tiles are found to last for years, and are easily replaced from below without disturbing any part of the furnace. Checker-work, deflecting arches, etc., have been used with varying success in the main combustion-chamber in the rear of the bridge-wall, and, in connection with hot-blast through a hollow bridge, will give, within a reasonable limit, practically smokeless combustion.

These boilers are built complete in the shop, are not sectional, and can be more easily handled in transporting and erecting than the cylindrical type.

For sizes over 250 horse-power they are preferably shipped in parts, and riveted together at their destination.

Mr. J. P. Witherow, after a searching analysis of their record in the Mississippi valley, has adopted these boilers as the best type for use in iron and steel furnaces and mills, and is building a large shop with improved machinery, at New Castle, Pa., to manufacture them, his first order being for 2500 horse-power for the Troy Steel and Iron Company, which company has two smaller ones just erected. Two of 250 horse-power each, are being built to run on producer-gas, with hot-blast, at the Tudor Iron Works in East St. Louis, Ill.

A number of tests made by disinterested experts, with the common bituminous coals of the Southern Illinois Basin, are here appended to show the comparative work of the ordinary horizontal tubular and the Heine boilers.

| Comparative Tests of Boiler Performance with Southern Illinois Coals, at St. Louis, Mo., 1884–85. | Horizontal Tubular Boilers. | | | | | | Heine Safety (Water-tube) Boilers. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | 5 feet diameter, 16 feet long, 36 4″ tubes. | 4 feet diameter, 26 feet long, 8 9″ tubes. | 4 feet diameter, 22 feet long, 12 6″ tubes. | 5 feet diameter, 22 feet long, 20 6″ tubes. | 5 feet diameter, 22 feet long, 20 6″ tubes. | *Totals* and *averages* of 5 preceding columns. | 4 ft. x 19 ft. shell. 85 tubes, 3½″ x 16 feet. | 4 ft. x 19 ft. shell. 85 tubes, 3½″ x 16 feet. | Two shells, 30″ x 19 feet. 113 tubes, 3½″ x 16 feet. | Two shells, 30″ x 19 feet. 113 tubes, 3½″ x 16 feet. | *Totals* and *averages* of 4 preceding columns. |
| Number of boilers | 1 | 1 | 2 | 2 | 2 | Total, 8 boilers. | 1 | 1 | 4 | 4 | Total, 10 boilers. |
| Duration of test, hours | 82.5 | 9 | 5 | 10 | 5 | Total, 111.5 hours. | 10 | 5 | 369.3 | 100 | Total, 484.3 hours. |
| Square feet of heating-surface | 750 | 705 | 1,199 | 1,860 | 1,860 | Total 6,374 sq. ft. | 1,287 | 1,287 | 6,760 | 6,760 | Total, 16,094 sq. ft. |
| Square feet of grate-area | 24 | 22.5 | 42.5 | 41 | 41 | Total, 171 sq. ft. | 35 | 35 | 192 | 192 | Total, 454 sq. ft. |
| Ratio of heating-surface to grate-area | 31 | 31 | 28.2 | 45.3 | 45.3 | Average, 37.3. | 36.7 | 36.7 | 35.2 | 35.2 | Average, 35.5. |
| Temperature of feed-water, deg. Fahr | 164.6 | 197.3 | 81.0 | 214 | 202 | Average, 171.8° F. | 106.1 | 202 | 199.6 | 185 | Average, 173.2° F. |
| Steam-pressure, lbs. per sq. inch | 52.1 | 78.5 | 87.0 | 92.4 | 98 | Average, 81.6 lbs. | 92.4 | 97 | 106 | 120 | Average, 103.6 lbs. |
| Total lbs. coal fired per hour | 686.06 | 550 | 983 | 990 | 1,260 | ..... | 870 | 1,200 | 3,459 | 4,554 | ..... |
| Coal per sq. ft. grate-area per hour, lbs. | 28.58 | 24.4 | 23.13 | 24.15 | 30.7 | Average, 26.18 lbs. | 24.8 | 34.3 | (14 to 30) 18 | 23.7 | Average, 25.2 lbs. |
| Percentage of ashes and refuse | 12.57 | 14.8 | 8.0 | 11.6 | 11.6 | Average, 11.7 per ct. | 6.4 | 15.5 | 16 | ..... | Average, 12.6 per ct. |
| Water evaporated per hour (actual conditions), lbs. | 8,939 | 2,905 | 5,217.2 | 5,765.4 | 8,170.4 | ..... | 5,829.2 | 8,663.1 | 26,788 | 34,927.6 | ..... |
| Water from and at 212° per sq. ft. heating-surface per hour, lbs. | 5.70 | 4.33 | 5.13 | 3.21 | 4.61 | Average, 4.59 lbs. | 5.19 | 7.06 | (2.5 to 7) 3.96 | 5.54 | Average, 5.43 lbs. |
| Water from and at 212° per lbs. coal | 6.18 | 5.54 | 6.25 | 6.02 | 6.80 | Average, 6.16 lbs. | 7.68 | 7.58 | 7.73 | 8.23 | Average, 7.80 lbs. |
| Water from and at 212° per lbs. combustible | 7.05 | 6.53 | 6.74 | 6.82 | 7.70 | Average, 6.97 lbs. | 8.24 | 8.98 | 9.20 | ..... | Average, 8.81 lbs. |
| U. S. standard H. P. developed | 136.2 | 99.4 | 205 | 191.2 | 274.6 | ..... | 195.6 | 291.6 | (650–1525) 856 | (792–1533) 1,131 | ..... |

All the tests above recorded were made under actual running conditions, and the commercial "dryness" of the steam was shown by the satisfactory running of the engines, mostly of the automatic cut-off type. The coal was taken as it is bought, without attempting to determine or deduct its percentage of moisture. Summed up, these nine tests show that with about the same temperature of feed-water, quantity of coal per unit of time and of grate-area, and with the same quality of fuel, the Heine boilers, while carrying 25 per cent. more pressure, gave 18½ per cent. more evaporation per square foot of heating surface, and nearly 27 per cent. more work per pound of fuel, than the horizontal tubular boilers.

It is but fair to add, that most tests made on these coals, with horizontal tubular boilers, show poorer results than those given in the table, while there are much higher results reported for the Heine, which I do not give here, having been unable to verify them to my satisfaction.

---

## COLORADO ORE-DEPOSITS.

(*Note by the Secretary.*)

The two papers by Mr. C. M. Rolker, "Notes on Certain Iron-Ore Deposits in Colorado," and "Notes on the Leadville Ore-Deposits," printed at pages 266 and 273 of this volume, were put to press (owing to the author's absence from the country) without final revision by him. The following corrections are thus made necessary:

On page 272, line 13 should read, "respectively 12 and 4 feet" (instead of 12 and 14).

On the same page, line 6 from the bottom should read, "the remaining 360 feet" (instead of 320).

On page 284, lines 23 and 24 should read, "In some places, the dolomite sand roof has remained thicker; and in isolated parts of the bed no replacement has occurred."

# INDEX.

[NOTE. In this Index, authors' names are printed in small capitals, and the titles of papers in italics. Casual references, giving little or no information about the subject, are indicated by inclosing the page-numbers in brackets. The distinction between such references and those not thus marked is not always sharply definable; but when a title is followed by page-numbers both with and without brackets, it may be assumed that the latter indicate the places where the greater amount of information will be found.]


ABBOTT, ARTHUR V., *Present Value of Steel Castings* [319], 351.
Abittibi River, Canada, Petroleum on, 696.
Acadia coal-mines, Colchester County, Nova Scotia [323], 407.
Acadia iron-mines, Nova Scotia, Canada, 539.
Albany River, Canada, Lignite on, 695.
Albion coal-mine, Pictou County, Nova Scotia, 317 [323], 405, 407.
Albion iron-mine, Pictou County, Nova Scotia, 61.
Alexandrowsky steel-works, St. Petersburgh, Russia, 464.
Allegany County, New York, Oil-pools in, 420 [425].
Allegheny Coal Measures, Pa., 642.
Allegheny County, Pa., Industrial Statistics of, 657 *et seq.*; Natural gas in, 437.
Allegheny Mountain, Pa., Coal-beds, 22.
Allen iron-mine, N. J. [909].
Almaden, Spain; Comparison of reduction works with those of New Almaden, Cal., 250.
Altoona, Pa., Elizabeth and Baker ore-banks at, 806.
Aluminum, Use of, in melting wrought-iron, 777.
*Amalgamation of Gold Ores, and the Loss of Gold in Chloridising-Roasting, with Especial Reference to Roasting in a Stetefeldt Furnace* (STETEFELDT) [319], 336.
Amie silver-mine, Leadville, Colorado [288].
Anderson County, Tennessee, Coal in [295].
Andover iron-mine, N. J. [905].
Angel, C. D., "Belt-theory" of location of oil, 438.
Angleur Steel-works, Belgium, 488.
Annapolis Royal, Nova Scotia, Visit to [323].
Anthracite in Hudson's Bay territories, 695.
Anthracite in Pennsylvania, 706.
Anticlinal theory of natural gas, 654.
Analyses: Of anthracite coal: *Pennsylvania:* Bast, 725; Bear Run, 724, 725; Beechwood, 725; Big Tracy, 726; Brookside, 724; Boston Run, 724, 725, 726; Buck Mountain, 726; Coleraine, Mammoth, 718; Coleraine, Wharton, 718; Colket, 725; Conner, 724; Eagle Hill, 725; East Franklin, 725; Ebervale, Mammoth, 718; Ellengowan, 726; Elmwood, 724; Furnace, 724; Gilberton, 724; Gilberton, Buck Mountain, 719; Girard, 724; Glendower, 725; Gilberton, Primrose,

719, 726; Gilberton, Seven-Foot, 719, 726; Hammond, 724, 725; Indian Ridge, 724, 726; Jeansville, Mammoth, 718; Jeddo, Mammoth, 718; Knickerbocker, 724; Lehigh, 715, 720; Lehigh, Mammoth, 719; Lehigh, Primrose, 717; Lehigh, Red Ash, 719; Lehigh, Wharton, 717; Locust Spring, 725, 726; Loyalsock, B. coal-bed, 717; Mahanoy City, 725, 726; Merriam, 725; Mine Hill Gap, 725; Mt. Carmel Shaft, 725; North Ashland, 725; North Mahanoy, 724, 726; Orchard, 726; Panther Creek, 714; Phœnix Park, 725; Pine Forest, 725; Plank Ridge, 724; Plymouth, Bennett, 718; Plymouth, Cooper, 718; Potts, 725; Pottsville, 725; Preston No. 1, 725; Nos. 3 and 4, 724; Pyne, 725; Richardson, 725; Schuylkill, 724; Shenandoah, Buck Mountain, 717; Shenandoah City, 724; Shenandoah, Mammoth, 719 *et seq.*; Shenandoah, Primrose, 719; Shenandoah, Seven-Foot, 717; Skidmore, 726; St. Nicholas, Buck Mountain, 719; St. Nicholas, Mammoth, 718; Thomaston, 725; Turkey Run, 724; Wadesville, 725; West Shenandoah, 725; Wilkes-Barre, Baltimore, 718; Yorktown, Mammoth, 718; Yorktown, Wharton, 718.

Of bituminous coal: 27, 28, 29, 30, 31; *Illinois*, 559; *Indiana*, 559; *Iowa*, 559; *Missouri*, 559; *Pennsylvania*, 559; Connellsville, 177; Freeport Lower, 22, 23; Kittaning Lower, 22, 24; *Tennessee:* Cocke County, Whitwell, 177; Grundy County, Tracy City, 177, 178; Hedley & Hoge, 177; New River coal-field, 303; Poplar Creek, 304; *Utah:* Castledale, 812; Cedar City, 812; *Virginia*, 559; OTHER COUNTRIES: *Nova Scotia:* Pictou, 560; Cape Breton, Sydney, 560; *England:* Derbyshire, 559; Newcastle, 559; Pease's West, 177; Staffordshire, 559; Yorkshire, 560; *North Wales*, 560.

Of blast-furnace cinder: *Pennsylvania:* Pottstown, Warwick, 837, 840, 842, 848.

Of blast-furnace dirt, 842.

Of car-wheel iron, 797, 918.

Of cast-iron: *Pennsylvania:* Altoona, 797.

Of cement copper, 115.

Of clay: *Maryland:* Mount Savage, 701.

Of coke: *Pennsylvania:* Connellsville, 364; *Utah:* Cedar City, 812; *Nova Scotia:* Pictou County, 63.

Of fire-sand: *Massachusetts:* Berkshire, 759; *New Jersey:* 759; *New York:* Clinton County, Mooer's Forks, 759; *Pennsylvania:* Mifflin County, Juniata, 759.

Of gold-ores: *Mexico:* Coahuila, Panuco, 200, 202, 203.

Of iron-ores: *Alabama:* Birmingham, Morris, 179; *Colorado:* Chaffee County, magnetites, 273; Costilla County, Pacer Station, magnetite, 271; Leadville, Breece Hill, red hematite and magnetite, 270; Saguache County, brown hematite and yellow ochre, 270: *Michigan:* Lake Superior, specular and hematite, 364; *New Jersey*, magnetite, 857; Andover, 910; Glendon, 910; Hibernia, 910; Mount Hope, 910; *Pennsylvania:* Berks County, Wheatfield [879], 895; Boyertown, magnetite, 857; Boyertown, Phœnix, 895; Warwick, 895; Dillsburg, 881; Lebanon County, Cornwall, 892, 893, 894, 895; Pottstown, magnetic, 842; Reading, island [879], 895; Seisholtzville, magnetite, 857; Underwood, 895; *Tennessee:* Inman, fossil ore, 175, 179; *Utah:* Adams, 812; Armstrong, 812; Smith, 812; OTHER COUNTRIES: *Nova Scotia:* Pictou County, bog iron-ore, 62; clay-ironstones and black-band ore, 62; limonite, 57, 60; red hematite, 59; spathic, 61; specular, 57.

Of limestone: *Pennsylvania:* Dillsburg, 882: *Nova Scotia:* Pictou County, 63.

Of magnesia, 460.

Of magnesian mineral: *Pennsylvania:* Cornwall, 881.

Of mill-cinder, 857.
Of mother-liquor employed in Longmaid process, 107.
Of phosphate-rock, South Carolina, 83.
Of pig-iron: *Tennessee:* South Pittsburgh, 180.
Of purple ore, or residue from lixiviation of roasted pyrites, 109.
Of roasted pyrites, 99 *et seq.*
Of silver-ores: *Arizona:* Charleston, Knoxville, 399; *Colorado:* Leadville, Minnie, 189; Leadville, Moyer, 288; *Mexico:* Zacatecas, Sombrerete, 395, 396.
Of steel (Bessemer): *New York:* Troy, 144; *Pennsylvania:* Bethlehem, 932; Pittsburgh (Clapp-Griffiths), 140, 141, 143.
Of steel boiler-plates, 815.
Apatite: In Hudson's Bay territories, 697; Its association with iron-ore, 811.
Apatite region of Canada, 495.
Apollo gas-well, Armstrong County, Pa., 435, 667.
ARCHIBALD, SIR ADAMS G., Address at Halifax meeting, 310.
Arisaig iron-mine, Pictou County, Nova Scotia, 59.
Armstrong oil-pool, Pennsylvania; 424 [425], 431.
Arsenic, Use of, as a destroyer of injurious insects, 496.
Asbestus in Hudson's Bay territories, 696.
ASHBURNER C. A., *The Classification and Constitution of Pennsylvania Anthracites* [595], 706; *The Geology of Natural Gas* [321], 428; *The Product and Exhaustion of the Oil Regions of Pennsylvania and New York* [320], 419; Remarks on waste of coal, 409.
Ashe County, North Carolina, iron and copper sulphides, 81.
Asphalt in Hudson's Bay territories, 696.
Associates: Election of, Chattanooga meeting, 14; Halifax meeting, 321; Pittsburgh meeting, 598; Change of status to members, 14, 321, 598.
Athabasca River, Canada, petroleum, 696.
A. Y. silver-mine, Leadville, Colorado [188].

Baddeck, Victoria County, Nova Scotia, Entertainment at [323].
Baie St. Paul, Blast-furnaces, Canada, 520.
Baker ore-bank, near Altoona, Pa., 806.
Banks' Land, coal, 695.
BARTLETT, J. H., *The Manufacture of Iron in Canada* [319], 508.
Basic open-hearth furnaces, 475.
*Basic Refractory Materials* (EGLESTON) [320], 455.
Batiscan iron-mine, Province of Quebec, Canada, 518.
Battle Islands, Lake Superior, blende on, 693.
BAYLES, JAMES C., Presidential address at Chattanooga meeting, 3; Presidential reply to address of welcome at Halifax meeting, 316; *Professional Ethics*, presidential address at Pittsburgh meeting [589], 609; *The Engineer and the Wage-earner*, presidential address at Halifax meeting [321], 327.
Beaver County, Pa., coal [24], 644.
Beaver Dam synclinal, Nova Scotia [679].
Beaver Falls, Pa., natural gas, 667.
Beaver Run coal-mine, Clearfield County, Pa., 27.
Beaver Run gas-well. Westmoreland County, Pa., 435.
BEEBE, ALFRED L., *Note on the Reduction of Ferric Solutions by the Use of Amalgamated Zinc and Platinum Foil* [595], 706.
BELL, ROBERT, *The Mineral Resources of the Hudson's Bay Territories* [595], 690.

Bernice anthracite coal-bed, Pa., Geology of, 722.
Bertrand silver-mill Nevada, 497 *et seq.*
Bessemer steel (see Steel).
Big Black Island, Lake Winnipeg, Canada, hematite, 691.
Big Pittsburgh silver-mine, Leadville, Colorado [288].
*Biographical Notice of Oswald J. Heinrich* (RAYMOND) [593], 784.
*Biographical Notice of Professor C. O. Thompson* (MOEN) [13], 190.
Birdsboro, Pa., E. & G. Brooke Iron Company, 784.
BIRKINBINE, JOHN, *Operation of Warwick Furnace, Pa., from August 27th, 1880, to September 1st, 1885* [595], 833; *The Distribution and Proportions of American Blast-furnaces* [320], 561.
Birmingham iron-mines, Jefferson County, Alabama [79].
Birmingham, Alabama, visit to, 15; Morris iron-ore, 179.
Black Bay, Canada, magnetite, 691.
Black Rock iron-mine, Pictou County, Nova Scotia, 60.
Blake crusher, Improvements in, 498.
BLAKE, W. P., *The Iron-Ore Deposits of Southern Utah* [594], 809.
Blanchard iron-mine, Pictou County, Nova Scotia, 58.
Blast-furnace hearth, chilled, 779.
Blast-furnaces in America, 561; Spiegel-furnaces at Newark, N. J., 89; Straight or no-bosh blast-furnace, 88.
BLAST-FURNACES OF THE UNITED STATES: *Illinois:* Cook County, North Chicago Rolling Mill Company, 362; *Missouri:* Midland [929]; Sligo [929]. *New Jersey:* Chester, 88, 862, 863; Greenwood Lake, Ringwood [905]. *Pennsylvania:* Allegheny County, Carrie, 658, Clinton, 658, Edgar Thomson, 658, 780, Edith, 658, Eliza, 658, Isabella, 147, 658, 861, Lucy, 658, Shoenberger, 658, Soho, 658; Berks County, Birdsboro, E. & G. Brooke Iron Company, 784; Bucks County, Durham, 130 [858], 862; Pottstown, Warwick, 833; OTHER COUNTRIES: *Canada:* Nova Scotia, Bloomfield, 539; Nictaux, 539; Ontario, Madoc, 531; Quebec, Baie St. Paul, 520; Grantham, 520; St. Francis River Mining Company, 520; *England:* Clarence, 368; Consett, 368; Ormsby, 368.
Block House coal-mines, Cape Breton, Nova Scotia, 548, 553, 557, 558.
Bloomfield blast-furnace, Nova Scotia, Canada, 539.
Bog iron-ore, Pictou County, Nova Scotia, 62.
Boiler-plates: Failure of steel, 812; Soft steel for, 826; Steel, specifications for, 830.
Bolts and screw-threads, Experiments with, 90.
Bower-Barff process, as applied to mercury condensers, 217.
BOWRON, W. M., *The Geology and Mineral Resources of the Sequatchie Valley, Tennessee* [12], 172.
BOYD, C. R., *Utilization of the Copper and Iron Sulphides of Virginia, North Carolina, and Tennessee* [12], 81.
Boyd's Hill gas-well, Pittsburgh, Pa., 649.
Boyertown iron-mines: Berks County, Pa., magnetic [879].
Braddock, Pa., visit to Edgar Thomson Steel Works, 604.
Bradford oil-region, McKean County, Pennsylvania, 420 [425], 433 [651].
BRAINERD, ALFRED F., *Note on Deposit of Fire-Sand in Clinton County, N. Y.* [595], 757; *Colored Mining Labor* [13], 78.
Breece Hill, Leadville, Colorado, Hematite deposit on, 270.
Bridgeport coal-mines, Cape Breton, Nova Scotia [323].
Bridge works in Allegheny County, Pa., 670.

Brookville coal-bed, Pa. [23], [643].
Brownsville coal-bed, Pittsburgh, Pa., 626.
Bruce copper-mine, Canada, 692.
Brückner cylinders, improved, 576.
Brush Creek coal-mine, Sequatchie County, Tennessee, 177.
Brush Creek, Montgomery County, Virginia, Gold deposits in, 83.
Buckingham Township, Canada, Apatite in, 495.
Buhrstone iron-ore, 645.
Building Stones in Hudson's Bay territories, 697.
Bullion, Process used for refining coppery, 731.
Butler County, Pennsylvania, Natural gas in, 668; Petroleum in, 424 [425], 431, 647, 668.

CABOT, JOHN W., *The Influence of Temperature in Steel-making upon the Behavior of the Ingots in Rolling* [13], 84.
Caledonia coal-mine, Cape Breton, Nova Scotia, 552, 557, 558.
Callaghan Creek, Va., Iron-ores on, 808.
Calumet iron-mine, Chaffee County, Colorado, 271.
Cameron County, Pa., coal, 33.
Campbell County, Tennessee, coal [295].
Campbell, E. D.: his colorimetric process for estimating phosphorus in iron and steel [319], 382.
CAMPBELL, H. H., *The Homogeneity of Open-hearth Steel* [319], 358.
Canada, Apatite in, 495.
Canada, Iron manufacture in, 508.
Canadian Titanic Iron Company, 520.
Canonsburg gas-well, Washington County, Pa., 437.
*Cape Breton Coal-Field* (ROUTLEDGE) [319], 542.
Cape Breton County, Nova Scotia, coke, 317; Excursion to, 323.
Cape Jones, Canada, Silver at, 693.
Cape Wolstenholm, Hudson's Bay, Red granite at, 698.
Cap de la Madelaine iron-mine, Province of Quebec, Canada, 508.
Carbide of iron in cast-iron, 799.
Carbon: Combined, in cast-iron, 797; Its estimation in iron and steel, 374; Its existence in iron, 914; Its influence in steel castings, 127.
Carbonate Hill, Leadville, Colorado, Geology of, 280.
Careyville, Campbell County, Tennessee, coal [293].
Caribou gold district, Nova Scotia [679], 689.
Carleton County, New Brunswick, Canada, Iron-ore in, 535.
Carpenter gas-well, Daum farm, Westmoreland County, Pennsylvania, 431.
Carrie blast-furnace, Allegheny County, Pa., 658.
Carroll County, Virginia, Iron and copper sulphides in, 81.
Car-wheel iron, Analyses of, 797, 918.
Cascade coal-mine, Elk County, Pa., 30.
Cast-iron, Analysis of, 797; Carbide and phosphide in, 799.
Cast-iron borings, Sampling of, 760.
Castledale, Utah, coke, 812.
Cattaraugus County, New York, oil-pools, 420.
Cedar City, Utah, coal, 811.
*"Centennial" and "Lotta" Gold Properties, Coahuila* (FRAZER) [13], 196.
Centre County, Pa., coal, 33; Iron-mines in (brown hematite) [879].

CHALFANT, JOHN M., Address of welcome at Pittsburgh meeting [589].
Champlain County, Quebec, Canada, Iron in, 508 *et seq.*
CHANCE, H. M., *The Relative Value of Coals to the Consumer* [13], 19.
Chartiers Creek, Pennsylvania, oil-wells at, 431.
Chattanooga, Tennessee, meeting: Proceedings of, 1; Papers of, 17.
Chautauqua County, New York, Gas-well in, 428.
CHEEVER, PROF. BYRON W., *E. D. Campbell's Colorimetric Process for Estimating Phosphorus in Iron and Steel* [319], 382; *The Estimation of Manganese, Carbon, and Phosphorus in Iron and Steel* [319], 372.
Cherry Grove oil-pool, Warren district, Pennsylvania, 422.
Chester blast-furnace, N. J., 862, 863.
Chesterfield Inlet, Canada, Iron pyrites, 697; Mica, 696.
Chezet Cook synclinal, Nova Scotia [679].
Chignecto coal-mine, Nova Scotia, Canada, 541.
*Chilled Furnace-hearth* (GAYLEY) [595], 779.
CHISM, RICHARD E., *The New Mining Code of Mexico* [13], 34.
Chloridizing-roasting, loss of gold in, 339.
CHRISTY, S. B., *Quicksilver Condensation at New Almaden* [13], 206.
Chromic iron, Mackenzie River, Canada, 697.
Chrysolite silver-mine, Leadville, Colorado, 276, 284, 286, 287, 288, 289.
Churchill River, Canada, Quartzites on, 697.
Cinder, blast-furnace, Analyses of, 837, 840, 842, 848.
Cinder, mill, Analysis of, 857.
CLAPP, GEORGE H., Remarks on methods for estimation of manganese and phosphorus in iron and steel, 379.
*Clapp-Griffiths Converter: Later Practice and Commercial Results* (WITHEROW) [594], 919.
*Clapp and Griffiths Process* (HUNT) [13], 139.
Clapp-Griffiths process for steel manufacture [789], 791; Works in operation or construction in the United States, 919 *et seq.* Visit to works at Pittsburgh, Pa., 604.
Clarence furnace, England, Work of, 368.
Clarendon oil-pools: *Pennsylvania*, Warren County, 420, 422.
Clarion County, Pa., Coal in, 29, 626 [643]; Oil-pools in, 424 [425], 431.
CLARK, F. W., *Lixiviation and Amalgamation Tests* [319], 395.
*Classification and Constitution of Pennsylvania Anthracites* (ASHBURNER) [595], 706.
Claudet process for the precipitation of gold and silver, 110.
Clay: Analysis of, 701; Calcination of, 702.
Clay-ironstone: on Milville Island, Hudson's Bay Territory, 691; in Pictou County, Nova Scotia, 62.
Clay-mine on Savage Mountain, Maryland, 699.
Clearfield County, Pa., coal, 22, 27.
Clearwater River, Athabasca District, Glass sand on, 698.
Climax silver-mine, Leadville, Colorado [288].
Clinton blast-furnace, Allegheny County, Pa., 658.
Clinton County, Pa., coal, 33.
Clinton County, N. Y., fire-sand, 757.
Closson, P., process for manufacturing magnesia, 458.
Clyde coal-mines, Cape Breton, Nova Scotia, 552, 557, 558.
Coal: Analyses of, 22, 23, 24, 27, 28, 29, 30, 31, 177, 178, 303, 304, 559, 560, 714, 715 *et seq.*, 812.

Coal, anthracite, at Commentruy, France, 626; Anthracites in Pennsylvania, 706; Bony coal, 721; Cannel coal in Pennsylvania, 644; Coal-product of Allegheny County, Pa., 666; Compression of coal in formation, 652; Geology of the Pittsburgh coal-region, 618; Its production in Georgia, Alabama, and Tennessee, 5; Relative values of coals to the consumer, 19.

Coal: *Ohio:* Trumbull County, 625; *Pennsylvania:* Allegheny Mountain, 22; Armstrong County, 22; Beaver County [24]; Brookville [23]; Cambria County, 22; Cameron County, 22; Centre County, 22; Clarion County, 22; Clearfield County, 22; Clinton County, 22; Elk County, 22; Freeport Lower, 22, 27; Freeport Upper [23]; Jefferson County, 22; Johnstown District [24]; Kittanning Lower, 22; Kittanning Upper [23]; Lawrence County, 24; McKean County [23], 33; Mercer County [24], 624; Moshannon Creek, 34; Washington County, 634; Westmoreland County, 636; *Tennessee:* 292; Anderson County, Coal Creek [294]; Marion County, 177; New River, 296; Sequatchie Valley, 176; *Utah:* Cedar City, 811. *Hudson's Bay Territories:* 695; *Nova Scotia:* 317; Cape Breton, Sidney, 542; Pictou County, 63.

Coal-Mines of the United States: *Pennsylrania:* Armstrong County, Mahoning Coal Co., 30; Cambria County, Lloydsville, 30; Chest Creek, Melon, 30; Clarion County, Fairmount Coal Co., 29, 30, Fox, 30, Goheen's, 29, McCall, 30, Murphy, 29, Smullan, 29, Songer, 30, Wilkins, 29; Clearfield County, Beaver Run, 27; Davis, 27; Derby, 27; Eureka, 27; Franklin, 27; Karthaus, 27; Laurel Run, 27; Logan, 27; Mapleton, 27; Morrisdale, 27; Old Moshannon, 27; Penn, 27; Stirling, 27; Webster, 27; Elk County, Cascade, 30; Farmerdale, 30; St. Mary's Coal Co., 30; Jefferson County, Diamond, 28; Eshbaugh, 28; Hawk, 28; Hoover, 28; Huffman, 28; Hum's, 28; Keslar, 28; London, 28; McKee, 28; Pantall, 28; Patton, 28; Reynolds, 28; Seley, 28; Sharp, 28; Shiesley, 28; Sprague, 28; Strouse's, 28; Wachob, 28; Wingert, 28; Philipsburg, Williamson, 30; Westport, Merriman, 30. *Tennessee:* Anderson County, Knoxville Iron Company, 297; Franklin County, Sewanee [294]; Marion County, Griffiths Creek, 177; Little Sequatchie, 177; Sequatchee County, Brush Creek, 177. Other Countries: *Nova Scotia,* Cape Breton, Block House, 553, 557, 558; Bridgeport [323]; Caledonia, 552, 557, 558; Clyde, 552, 557, 558; Cow Bay [323]; Emery, 555, 557, 558; Gardiner, 556, 557, 558; Glace Bay, 317, 551, 557, 558, 627: Visit to [323]; Gowrie, 554, 557, 558; International, 317, 551, 557, 558; Lingan, 551, 557, 558; Low Point [323]; Lorway, 557, 558; Reserve, 554, 557, 558; Sydney, 317, 549, 557, 558; Schooner Pond, 553, 557, 558; Victoria, 543, 550, 557, 558; Chignecto, 541; Acadia [323]; Cumberland County, Spring Hill, 317, Visit to [323]; Drummond [323]; New Glasgow Vale, 405, 408; Pictou County, Albion, 317 [323]; Stellarton, Albion, Foord pit [405], 407; Drummond, 407; International, 317; Stellarton, Albion, 405, 407; St. George, 541; Westville, Acadia, 407.

Coahuila, Mexico, Gold properties in, 196.

Cobourg, Peterborough and Marmora Railway and Mining Company, Ontario, Canada, 531.

Coke, Analyses of, 63, 364; *Utah:* Castledale, 812; *Nova Scotia,* 317.

Coke manufacture in Pennsylvania, 667.

Colchester County, Nova Scotia, Iron in, 54, 57.

Coldbrook Rolling-mill, New Brunswick, Canada, 536.

Collingwood, Francis, Remarks on the present value of steel castings, 357.

Colorado, Iron-ore deposits in, 266.

*Colored Mining Labor* (Brainerd) [13], 78.

Colorimetric process for the estimation of manganese in iron and steel, 374, 330; for estimating phosphorus, 382.
Col. Sellers silver-mine, Leadville, Colorado [181], 187, 288.
COLTON, HENRY E., *The Upper Measure Coal-fields of Tennessee* [12], 292.
Commentruy, France, Anthracite coal-bed at, 626.
Compass, Mining, 870.
Comstock silver-mines, Nevada; Process for refining coppery bullion, 731.
Condensers used at New Almaden, Cal., 207.
Confederate iron-mines, Buchanan, Botetourt County, Va. [786].
Conglomerate coal-bed, Pa. [23].
Connellsville, Pa., Pittsburgh coal-bed at, 626 [637], 639, 652; Coke at, 667.
Consett blast-furnaces, England, Work of, 368.
*Contraction of Iron under Sudden Cooling* (HOWE) [320], 400.
COOK, EDGAR S., Remarks on "dirt troubles" in blast-furnaces, 859.
COOK, ROBERT A., *The Manufacture of Fire-brick at Mt. Savage, Md.* [595], 698.
Cooper oil-pool, Warren and Forest Counties, Pennsylvania, 422.
Copper, cement, Analysis of, 115.
Copper-mines: *Canada:* Ontario, Bruce, 692; Wellington, 692; Cape Breton, Coxheath [323]; *Mexico:* Coahuila, Panuco, 196.
Copper-ore in Hudson's Bay territories, 692.
Copper-sulphides of Virginia, North Carolina and Tennessee, Utilization of, 81.
Copper-works in Allegheny County, Pa., 665; at Duisbourg, Germany, 98 *et seq.;* at Oker, Germany, 98 *et seq.;* at Hemixem, Belgium, 98 *et seq.*
Coppermine River, Canada: Apatite at, 697; Copper at, 692.
Coprolites of the Virginia Peninsula [83].
*Cornwall Iron-Ore Mines, Lebanon, Pa.* (D'INVILLIERS) [594], 873.
Costilla County, Colorado, Magnetites in, 271.
Cow-Bay coal-mines, Cape Breton County, Nova Scotia [323].
Cowles's Electric Smelting Company, 495.
Coxheath copper-mines, Cape Breton County, Nova Scotia [323].
Creighton, Pa., Visit to; Pittsburgh Plate Glass Works at, 602.
Crescent Steel Works, Lawrenceville, Pa., Visit to, 603.
Creusot iron-works, France, 476.
Crownpoint silver-mine, Leadville, Colorado, 189.
Crozer iron-mine, Roanoke County, Virginia [79].
Cumberland County, Nova Scotia, Coal in, 404; Coke in, 317.
Cumberland Mountain, Tennessee, Geology of, 178.
*Cupel-Machine* (WAIT) [595], 767.

Darr's Hill gold district, Nova Scotia, 689.
Davis coal-mine, Clearfield County, Pa., 27.
Dayton Coal and Iron Company, Visit to works of, 15.
Delamater gas-well, Butler County, Pa. [668].
Derby coal-mine, Clearfield County, Pa., 27.
Derry township, Canada, Apatite in, 495.
Diamond coal-mine, Jefferson County, Pa., 28.
Dickerson iron-mine, Succasunna, Morris County, N. J., 904.
Dillsburg, Pa., Iron-ore, Analysis of, 881.
D'INVILLIERS, E. V., *The Cornwall Iron-Ore Mines, Lebanon, Pa.* [594], 873.
*Distribution and Proportions of American Blast-Furnaces* (BIRKINBINE) [320], 561.

Dolomite, Silurian and Carboniferous, of Leadville, Colorado, 276 *et seq.*
Dome silver-mine, Leadville, Colorado [182] [188].
Draft arrangement, Recent improvements in, 256.
Drifton, Pa., Industrial School for Miners and Mechanics [788].
Drug-Brook iron-mine, Pictou County, Nova Scotia, 56.
Drummond coal-mines, Nova Scotia [323], 407.
Drummond County, Canada, Iron in, 520.
Ducktown, Tennessee, Iron and Copper sulphides in, 81 [84].
DUDLEY, C. B. (and F. N. PEASE), *Notes on the Constitution of Cast-Iron* [594], 795.
Dudley, C. B., Remarks on Clapp-Griffiths process, 938.
Duisbourg, Germany, Copper-works at, 98 *et seq.*
Duncan Glass Works, Pittsburgh, Pa., Visit to, 604.
Dunkard Creek, Green County, Pennsylvania, oil-region [425], 431, 620, 642.
Dunkin silver-mine, Leadville, Colorado [284].
Dunlap Creek, Fayette County, Pennsylvania, oil-pools [425], 431.
*Durham Blast-Furnace* (FACKENTHAL) [12], 130.
Durham blast-furnace, Pa. [858], 862.

E. & G. Brooke Iron Company's Steel-works (Clapp-Griffiths), Birdsboro, Pa. [922].
East Liverpool, Ohio, natural gas, 667.
E. D. Campbell's *Colorimetric Process for Estimating Phosphorus in Iron and Steel* (CHEEVER) [319], 382.
Edgar Thomson blast-furnaces, Pittsburgh, Pa., 658, 780.
Edgar Thomson Steel Works, Braddock, Pa., Visit to, 604.
Edge Moor Iron Company, Wilmington, Delaware [129].
Edith blast-furnace, Allegheny County, Pa., 658.
EGLESTON, PROF. THOMAS, *Basic Refractory Materials* [320], 455; *Treatment of Roasted Pyrites by the Longmaid and Claudet Processes for the Extraction of Gold and Silver* [13], 98; Remarks on failures of steel boiler-plates, 823.
Election of members and associates: Chattanooga meeting, 14; Halifax meeting, 320; Pittsburgh meeting, 596, 597, 598.
*Electrical Furnace for Reducing Refractory Ores* (HUNT) [319], 492.
Elizabeth iron-mine, Cornwall, Pa., magnetic, 891.
Elizabeth ore-bank, Altoona, Pa., 806.
Eliza blast furnaces, Allegheny County, Pa., 658.
Elk County, Pa., coal, 33; natural gas, 434, 436.
Emery coal-mine, Cape Breton, Nova Scotia, 555, 557, 558.
Emmons's blue limestone, Leadville, Col., 276, 282.
*Engineer and Wage-Earner* (BAYLES) [321], 327.
Eshbaugh coal-mine, Jefferson County, Pa., 28.
*Estimation of Manganese, Carbon, and Phosphorus in Iron and Steel* (CHEEVER) [319], 372.
Eureka coal-mine, Clearfield County, Pa., 27.
Evening Star Silver-mine, Leadville, Col. [284], 287.
*Experiments with Bolts and Screw-Threads* (KING) [13], 90.
Explosives: Apparatus for determining their relative strength, 75.

FACKENTHAL, B. F., JR., *The Durham Blast-Furnace* [12], 130.
Fairmount coal-mine, Clarion County, Pa., 29, 30.
Falcon Island, Canada, Soapstone at, 695.

Fall Brook iron-mine, Pictou County, Nova Scotia, 59.
Farmerdale coal-mine, Elk County, Pa., 30.
Farnley iron-works, Leeds, England, 476.
Fayette County, Pa., coal, 636; Iron, 646; Oil-pools [425].
Fiedler condenser, 215.
Fifteen-Mile Stream gold-district, Nova Scotia [679], 689.
Fire-brick hot-blast stove, 159.
Fire-brick manufacture at Mount Savage, Maryland, 698.
Fire-sand, Analyses of, 759; in Clinton County, N. Y., 757.
*Flow of Air and Other Gases in Pipes* (GORDON) [12], 146.
Floyd County, Va., gold-deposits, 83.
Fond du Lac, Canada, graphite, 696.
Foord coal-pit, Albion mines, Stellarton, Nova Scotia [405], 407.
FORD, S. A., Remarks on the wearing properties of chilled car-wheels, 939.
Forest County, Pa., oil-pools, 420, 422 [651]; Natural gas in [437].
Fork Run, Va., iron-ores, 808.
Fox coal-mine, Clarion County, Pa, 30.
Franklin coal-mine, Clearfield County, Pa., 27.
Franklin oil-pool, Venango County, Pa., 422.
FRAZER, DR. PERSIFOR, *The "Centennial" and "Lotta" Gold-Properties, Coahuila* [13], 196.
FREELAND, FRANCIS T., *The Sulphide-Deposits of South Iron Hill, Leadville* [13], 181.
Freeport coal-beds, Pa., 626 [643]; Lower bed, 22, 27; Upper bed [23].
Fredonia, Chautauqua County, N. Y., gas-wells, 428, 436.
Fremont County, Col., magnetite, 271.
French River, Pictou County, Nova Scotia, red hematite, 61.
Fryer Hill, Leadville, Col., carbonate ores, 275 *et seq.*
Fuels, Proposed apparatus for determining the heating power of, 727.
Furnace Falls Iron Company, Ontario, Canada, 532.

GAERTNER, ERICH G., *The Mining Compass and Trigonometer* [594], 870.
Galena silver-mill, Nevada, 501.
Gardiner coal-mine, Cape Breton, Nova Scotia, 556, 557, 558.
GARRETT, WILLIAM, *Peculiar Phenomena in the Heating of Open-Hearth and Bessemer Steel* [594], 789.
GARRISON, F. LYNWOOD, *The Microscopic Structure of Car-Wheel Iron* [594], 913; *The Microscopic Structure of Iron and Steel* [12], 64.
Gas, natural, Geology of, 428.
Gases, The flow of, 146.
Gasoline-gas in a chemical laboratory, 769.
Gas-wells: Ohio: East Liverpool, 667. *Pennsylvania:* Allegheny County, Apollo, 667, Boyd's Hill [646], 649. Haymaker, 668, Tarentum [437], Westinghouse, 668; Armstrong County, Apollo, 435; Beaver Falls, 667; Butler County, Delamater [668]; Cattaraugus County, McMullen and Hallock, 436; Chautauqua County, Fredonia [436]; Elk County, Ridgway, 435, Wilcox, 436; Forest County, Marionville [437], Leechburg, 667; Venango County, Kane, 435; Warren County, Sheffield, 433, 436; Washington County, Canonsburg [437], Hickory [437]; Westmoreland County, Beaver Run, 435, Murraysville, 435 [437] Pine Run, 435, Roaring Run, 435. *West Virginia:* New Cumberland, 667.

GAYLEY, JAMES, *A Chilled Furnace-Hearth* [595], 779.
Gay's River, Nova Scotia, alluvial gold, 684.
Geology: Carbonate Hill, Leadville, Colorado, 280; Fryer Hill, Leadville, Colorado, 276; Iron Hill, Leadville, Colorado, 280; Iron County, Utah, 809; Lebanon County, Pa., 875; Low Moor, Va., 801; Nova Scotia gold-field, 676; Pictou County, Nova Scotia, 54; Pittsburgh coal-region, 618, 629; Sequatchie Valley, Tennessee, 172; South Mountain Chain, Pa., 449; Tennessee coal-field, 294; Yankee Hill, Leadville, Colorado, 280.
*Geology and Mineral Resources of the Sequatchie Valley, Tennessee* (BOWRON) [12], 172.
*Geology of Natural Gas* (ASHBURNER) [321], 428.
*Geology of the Low Moor, Va., Iron-ores* (LYMAN) [595], 801.
*Geology of the Pittsburgh Coal Region* (LESLEY) [594], 618.
GILPIN, E., JR., *The Iron-Ores of Pictou County, Nova Scotia* [13], 54; *The Nova Scotia Gold-mines* [595], 674; Remarks on explosions in coal-mines, and loss of coal, 409.
Glace Bay coal-mines, Cape Breton, Nova Scotia, 317, 546, 551, 557, 558, 627; Visit to [323].
Glacial phenomena of Nova Scotia [319].
Glasgow Iron Company's Steel-works (Clapp-Griffiths), Pottstown, Pa., 920.
Glass industry of Allegheny County, Pa., 665.
Glass sand in Hudson's Bay territories, 698.
Goderich, Canada, salt-works [788].
Goheen's coal-mine, Clarion County, Pa., 29.
Gold: in Hudson's Bay territories, 693; in Montgomery and Floyd Counties, Virginia, 83; Longmaid and Claudet processes for its extraction from roasted pyrites, 98.
Gold-mills: *South Carolina:* Haile, 506.
Gold-mines: *Mexico:* Coahuila, Centennial, 198, 204; Lotta, 202, 205; Vera Cruz, Las Minas, 336; Muertos, 336; *Canada:* Huronian, 693; *Nova Scotia:* Halifax County, Montagu, 322, 681, 689.
Gold-mining in Nova Scotia, 674.
Gold-ores: Amalgamation of, 336; Analyses of, 200, 202, 203; Exhibition of banded structure in a vein, 265; Experiments in amalgamation, 344; Experiments in roasting, 337.
GORDON, FREDERICK W., *The Flow of Air and other Gases in Pipes* [12], 146; *The Work of the Blast-Furnaces of the North Chicago Rolling Mill Company* [320], 362; Remarks on "dirt troubles" in blast-furnaces, 863.
Gowrie coal-mines, Cape Breton, Nova Scotia, 554, 557, 558.
Grand Pré, Kings County, Nova Scotia, visit to [323].
Grantham Blast-furnaces, Quebec, Canada, 520.
Grape Creek, Fremont County, Colorado, magnetites in, 271.
Graphite in cast-iron, 797, 919.
Graphite in Hudson's Bay territories, 696.
Grayson County, Virginia, iron and copper sulphides, 81.
Great Slave Lake, Canada, hematite, 691.
Great Slave Lake, Canada, petroleum, 696.
Great Whale River, Canada, hydraulic cement, 697.
Great Whale River, Canada, molybdenite, 693.
Great Whale River, Canada, silver, 693.
Greene County, Pa., coal, 634.
Griffiths Creek coal-mine, Marion County, Tennessee, 177.

Gunnison County, Colorado, magnetite, 271.
Gypsum in the Hudson's Bay territories, 694.

Haile gold-mill, South Carolina, 506.
Half-way House silver-mine, Leadville, Colorado, 284.
Haliburton County, Canada, iron, 532.
Halifax, Nova Scotia, meeting, Proceedings of, 307; Papers of, 325.
Halifax Iron-works, Nova Scotia, Canada, 541.
Hall's Valley, Colorado, hematite [270].
Halsbrücker Smelting Works, Freiberg, Saxony, 579.
Hamilton Rolling-mill, Ontario, Canada, 534.
Hastings County, Ontario, Canada, iron, 527, 531.
Hawk coal-mine, Jefferson County, Pa., 28.
Haycock iron-mine, Province of Quebec, Canada, 522.
Haymaker gas-well, Murraysville, Pa., 668.
H. D. silver-mine, Leadville, Colorado [186].
Hecla iron-mine, Chaffee County, Colorado, 271.
*Heine Safety-boiler* (MEIER) [594], 941.
Heinrich, Oswald J., Biographical notice of [593], 784.
Hemixem, Belgium, copper works, 98 *et seq.*
Hercules metal, 494.
Hibernia iron-mine, N. J., 904.
Hibernia silver-mine, Leadville, Colorado [288].
Hickory gas-well, Washington County, Pa. [437].
Hochelaga iron-works, Province of Quebec, Canada, 522.
HODGES, A. D., JR., *The Process used at the Comstock for Refining Coppery Bullion from the Amalgamation of Tailings* [595], 731.
*Homogeneity of Open-hearth Steel* (CAMPBELL) [319], 358.
Honeyman, Rev. D., Remarks on the Glacial Phenomena of Nova Scotia [319].
Hoover coal-mine, Jefferson County, Pa., 28.
Hörde, Germany, Manufacture of magnesia at, 458.
Hot Springs, Saguache County, Colorado, hematite, 268.
Houghton iron-works, Ontario, Canada, 531.
Houston iron-mines, Botetourt County, Virginia [79].
HOWE, H. M., *The Contraction of Iron under Sudden Cooling* [320], 400; Remarks on Clapp-Griffiths process, 929, 934.
Howell furnace, Comparison with Stetefeldt, 341.
Hudson's Bay territories, Mineral resources of, 690.
Hudson's Strait, Canada, graphite, 696; magnetite, 691; mica, 696.
Huffman coal-mine, Jefferson County, Pa., 28.
Hull blast-furnace, Ottawa, Quebec, Canada [519].
Hum's coal-mine, Jefferson County, Pa., 28.
HUNT, ALFRED E., *Soft Steel for Boiler-plates* [594], 826; Remarks on methods for estimation of manganese and phosphorus in iron and steel, 379.
HUNT, ROBERT W., *Clapp and Griffiths Process* [13], 139; Remarks on the Clapp-Griffiths process, 932.
HUNT, DR. T. STERRY, *An Electrical Furnace for Reducing Refractory Ores* [319], 492; *Note on the Apatite Region of Canada* [319], 495.
Huronian gold-mine, Canada, 693.
Huston's Cave, Greene County, Pa. [638].
Hydraulic cement, Hudson's Bay, 697.

Idria, Austria; Comparison of reduction-works with those of New Almaden, Cal., 215, 230, 231, 247.
*Improved Brückner Cylinders* (RAYMOND) [320], 576.
*Improvements in Ore-Crushing Machinery* (KROM) [319], 497.
Industrial School for Miners and Mechanics, Drifton, Pa. [788].
*Influence of Temperature in Steel-Making upon the Behavior of the Ingots in Rolling* (CABOT) [13], 84.
Ingham iron-mine, Page County, Virginia [79].
Inman iron-mine, Tennessee [79], 175.
International Coal-mines, Cape Breton, Nova Scotia, 317, 551, 557, 558.
Iron: Constitution of cast-iron, 795; Contraction of iron on sudden cooling, 400; Determination of titanium in, 763; Estimation of manganese, carbon, and phosphorus in, 372 *et seq.*, 382; Existence of carbon in, 914; Manufacture of, in the South, 4; Melting wrought-iron, 774; Microscopic structure of iron and steel, 64, 913; Mitis-castings from wrought-iron or steel, 773; Reduction of ferric-solutions by amalgamated zinc and platinum foil, 766; Sampling of cast-iron borings, 760; Utilization of sulphides of Virginia, North Carolina, and Tennessee, 81.
Iron County, Utah, iron-ore deposits, 809.
Iron Hill, Leadville, Colorado, Geology of, 280; Iron Hill Cons. silver-mine [188].
Iron-manufacture in Canada: Quebec, 508; Ontario, 523; New Brunswick, 535; Nova Scotia, 537.
Iron Mountain iron-mines, Allegheny County, Virginia [79].
Iron Mountain, Missouri, Occurrence of apatite at [811].
Iron pyrites in Hudson's Bay territories, 697.
Iron Silver Co. silver-mines, Leadville, Col., 287.
IRON-MINES OF THE UNITED STATES: *Alabama:* Jefferson County, Birmingham [79]. *Colorado:* Chaffee County, Calumet, 271; Hecla, 271; Smithville, 271; Leadville, Fryer Hill, 275; Kit Carson [275]; Little Eva [275] [288]; Pandora [275]. *Georgia:* Rising Fawn [79]. *Michigan:* Menominee district, 910. *New Jersey* [905]; Allen [909]; Hibernia, 904; Morris County, Succasunna, Dickerson, 904; Mount Pleasant [909]; Richards [909]. *New York:* Port Henry, No. 21, 910; Port Henry, Old Bed, 910. *Pennsylvania:* Berks County, Boyertown, magnetic [879]; Wheatfield [879], 895; Boyertown, Phœnix, 895; Warwick, 895; Centre County, brown hematite [879]; Cornwall, Elizabeth, magnetic, 891; Lebanon County, Cornwall, magnetic, 873; Reading Island [879], 895; Underwood, 895. *Tennessee:* Inman [79], 175; Roane County, Rockwood [79]; Allegheny County, Iron Mountain [79]. *Virginia:* Allegheny County, Low Moor [79]; Stack [79]; Botetourt County, Confederate [786]; Houston [79]; Middlesex County, Wilton, D. S. Cook [79]; Page County, Ingham [79]; Milnes [79]; Roanoke County, Crozer [79]; Rohrer [79]. OTHER COUNTRIES: *Canada:* Batiscan, 518; Cap de la Madelaine, 508; Province of Quebec, Haycock, 522; Moisic, 520; Radnor, 518; St. Maurice, 508; *Nova Scotia:* Acadia, 539; Pictou County, Albion, 61; Arisaig, 59; Black Rock, 60; Blanchard, 58; Drug Brook, 57; Fall Brook, 59; McLaren's Brook, 59, 60; McGregor, 61; Springville, 59, 60; Watson, 57; Weaver, 57; Webster, 58, 59.
Iron-ores, analyses of, 57, 59, 60, 61, 62, 63, 175, 179, 270, 271, 273, 364, 812, 842, 857, 881, 892, 893, 894, 895, 910, 912.
Iron-ore deposits in Colorado, 266.
Iron-ores: Distribution in the United States, 564; In Hudson's Bay territories, 691; Occurrence of apatite, 811; Purple ore, or residue from lixiviation of roasted

pyrites, 109; *Pennsylvania:* Altoona, Baker, 806; Elizabeth, 806; Marcellus ore-bed, 805. *Missouri:* Iron Mountain [811]. *New York:* Lake Champlain, Sandford [811]. *Virginia:* Callaghan Creek, 808; Fork Run, 808; Karnes Creek Valley, 808; Low Moor, 801. *Canada:* New Brunswick, Woodstock, 535; *Nova Scotia*, Colchester County, specular and limonite, 57; Pictou County, McLaren's Brook, 59, 61; specular and limonite, 56.
*Iron-Ore Deposits of Southern Utah* (BLAKE) [594], 809.
*Iron-Ores of Pictou County, Nova Scotia* (GILPIN) [13], 54.
Iron-Works: *Illinois*, East St. Louis, Tudor, 947. *New York:* Allegheny, Rolling-mills, etc., 660, 661; Troy, 947. *Canada:* Montreal, 523; New Brunswick, Coldbrook, 536; Portland Rolling-mill, 537; Nova Scotia, Halifax, 541; Moose River, 537; Ontario, Furnace Falls, 532; Hamilton, 534; Houghton, 532; Marmora, 527; Toronto, 532; Province of Quebec, Hochelaga, 522. *England:* Leeds, Farnley, 476. *France:* Creusot, 476.
Isabella blast-furnaces, Pittsburgh, Pa., 147, 658, 861.
Island iron-mine, Reading, Pa. [879], 895.

James's Bay, Canada, gypsum, 694.
Jefferson County, Pa., coal, 28; cannel coal, 644.
Johnstown District, Pa., coal [24].

Kane gas-well, Venango County, Pa., 435.
Karnes Creek Valley, Va., iron-ores, 808.
Karthaus coal-mine, Clearfield County, Pa., 27.
KENT, WILLIAM, *Proposed Apparatus for Determining the Heating Power of Different Fuels* [595], 727; *Recent Failures of Steel Boiler-Plates* [594], 812; Remarks on specific gravity of open-hearth steel, 585.
Keslar coal-mine, Jefferson County, Pa., 28.
KING, W. R., *Experiments with Bolts and Screw-Threads* [13], 90.
Kit Carson iron-mine, Leadville, Col. [275].
Kittanning coal-beds, Pa., 626 [643]; Lower Bed, 22; Upper Bed [23].
Knee Lake, Canada, magnetite, 691.
Knoxville Iron Company's coal-mine, Coal Creek, Anderson County, Tenn., 297.
Knoxville silver-mine, Charleston, Arizona [398].
KROM, STEPHEN R., *Improvements in Ore-Crushing Machinery* [319], 497.

Labor, Colored mining, 78.
Lake Nipigon, Canada, asbestos, 697; dolomites, 697.
Lake of the Woods, Canada, dolomites, 697; lignite, 695.
Lake Superior, graphite, 696.
Lake Winnipegosis, Canada, salt, 695.
La Plata silver-mine, Leadville, Col., 189.
La Saline, Canada, salt, 694.
Las Minas gold-mines, Vera Cruz, Mexico, 336.
Laurel Creek, Floyd County, Va., gold-deposits, 83.
Laurel Run coal-mine, Clearfield County, Pa., 27.
Law, Mining, of Mexico, 34.
Lawrence County, Pa., coal [24].
Lawrencetown synclinal, Nova Scotia [679].
Lawrenceville, Pa., Visit to Crescent steel-works at, 603.
Lead-refining in Allegheny County, Pa., 666.

Lead-mines in Wythe County, Va. [787].
Lead-ore in Hudson's Bay territories, 692.
Leadville, Col., ore-deposits of, 273; Sulphide deposits of South Iron Hill, 181. (See also Silver-mines.)
Lebanon County, Pa., iron-mines, 873.
Leechburg, Pa., natural gas, 667.
Leeds County, Ontario, Canada, iron manufacture, 523.
Leeds, England, Iron-works near, 476.
LEHMAN, A. E., *Topographical Models; their Construction and Uses* [319], 439.
LESLEY, J. P., *The Geology of the Pittsburgh Coal-Region* [594], 618.
Lexington silver-mill, Butte, Montana [343].
Liard River, Canada, Gold in, 693.
Lickdale Iron Company's steel-works (Clapp-Griffith), Lebanon, Pa. [922].
Lièôre District, Canada, Apatite-mining in, 495.
Lignite in Hudson's Bay territories, 695.
Lime in Hudson's Bay territories, 697.
Lime silver-mine, Leadville, Col. [188], 283.
Limonite (see Iron-ores, Iron-mines, and Analyses).
Limestone, analyses of, 63, 882.
Lingan coal-mines, Cape Breton, Nova Scotia, 550, 557, 558.
Lingan Tract, Sydney coal-field, Cape Breton, Nova Scotia, 545.
L'Islet Blast-furnace, Province of Quebec, Canada [519].
Little Chief silver-mine, Leadville, Col. [276], 286 [288, 289].
Little Eva iron-mine, Leadville, Col. [275, 288].
Little Pittsburgh silver-mine, Leadville, Col., 286 [288, 289].
Little Sequatchie coal-mine, Marion County, Tenn., 177.
Little Whale River, Canada, asbestos, 697; lead, 692.
*Lixiviation and Amalgamation Tests* (CLARK) [319], 395.
Lloydsville coal-mine, Cambria County, Pa., 30.
Locomotive Works in Allegheny County, Pa., 670.
Logan coal-mine, Clearfield County, Pa., 27.
London coal-mine, Jefferson County, Pa., 28.
London steel-works, Ontario, Canada, 535.
Londonderry, Colchester County, Nova Scotia, Excursion to, 322; Specular iron-ores, 539.
Long Island, Hudson's Bay, anthracite, 695; copper pyrites, 692; hematite, 691.
Longmaid and Claudet processes for the extraction of gold and silver from roasted pyrites, 98.
Lorway coal-mine, Cape Breton, Nova Scotia, 557, 558.
Loss of gold in chloridizing-roasting, 339.
Lotta gold-mine, Coahuila, Mexico, 202, 205.
Louisburg, Cape Breton, Nova Scotia, Visit to [323].
Lowe-Strong gas as a fuel, 253.
Lower Devonian rocks, Pa., 651.
Low Moor, Va., Geology of, 801.
Low Moor iron-mine, Allegheny County, Va. [79].
Low Point coal-mines, Cape Breton, Nova Scotia [323].
Lucy blast-furnaces, Allegheny County, Pa., 658.
Lunenburg, Nova Scotia, alluvial gold, 684.
LYMAN, BENJ. SMITH, *Geology of the Low Moor, Va., Iron-Ores* [595], 801.
Lyndhurst, Ontario, Canada, iron-manufacture, 523.
Lyon silver-mill, Dayton, Nevada, 731.

Mackenzie River, Canada, chromic iron, 697; gold, 693; petroleum, 696.
MACKINTOSH, J. B., *A New Method for the Determination of Phosphorus in Iron and Steel* [321], 385.
Mackintosh, Hon. J. C., Address at Halifax meeting, 315.
Madoc Blast-furnace, Ontario, Canada, 531.
Magnesia, Analyses of, 460; Processes for manufacturing, 458, 460.
Magnetic iron-ores (see Iron-ores, Iron-mines, and Analyses).
Mahoning coal-mine, Armstrong County, Pa., 30.
Manganese, Estimation of, in Iron and Steel, 372; Influence of, in steel-castings, 128.
Manitoba, Canada, gypsum, 694.
Manitounuck, Hudson's Bay, quartzites, 697.
Mansfield silver-works, Germany, 747.
*Manufacture of Fire-brick at Mt. Savage, Md.* (COOK) [595], 698.
*Manufacture of Iron in Canada* (BARTLETT) [319], 508.
*Manufacture of Steel Castings* (SALOM) [12], 118.
Mapleton coal-mine, Clearfield County, Pa., 27.
Marble Island, Hudson's Bay, Quartzites on, 697.
Marcellus iron-ore bed, Pa., 805.
Marion County, Tenn., coal, 177.
Marionville gas-well, Forest County, Pa. [437].
Marmora iron-works, Ontario, Canada, 527.
Matchless silver-mine, Leadville, Col. [288].
Mattagami River, Canada, iron pyrites, 697; soapstone, 695; lignite, 695.
Mauch Chunk red shale, Pa., 633, 646.
McCall coal-mine, Clarion County, Pa., 30.
McCormick steel-works (Clapp-Griffiths), Harrisburg, Pa. [922].
McGregor iron-mine, Pictou County, Nova Scotia, 61.
McKean County, Pa., coal [23], 33; oil-pools, 420; mountain sands, 648.
McKee coal-mine, Jefferson County, Pa., 28.
McLaren's Brook iron-mine, Pictou County, Nova Scotia, 59, 61.
McMullen and Hallock gas-well, Cattaraugus County, Pa., 436.
MEIER, E. D., *The Heine Safety-Boiler* [594], 941.
Melon coal-mine, Chest Creek, Pa., 30.
Melville Island, Canada, clay-ironstone, 691.
Members: Election of, at Chattanooga meeting, 14; at Halifax meeting, 320; at Pittsburgh meeting, 596.
Mendheim furnace, 464 *et seq.*
Menominee iron-mines, Lake Superior, 910.
Mercer County, Pa., coal [24], 625.
Merriman coal-mine, Westport, Pa., 30.
METCALF, WILLIAM, *Natural Gas*, 589.
Methy Portage, Canada, glass-sand, 698.
Mexico, Gold in, 196, 336; Mining in, 34.
Mica in Hudson's Bay territories, 696.
*Microscopic Structure of Car-Wheel Iron* (GARRISON) [594], 913.
*Microscopic Structure of Iron and Steel* (GARRISON) [12], 64.
Midland Blast-furnace, Missouri [929].
MILLER, G. S., *The Specific Gravity of Low-Carbon Steels* [320], 583.
Milnes iron-mine, Page County, Va. [79].
*Mineral Resources of the Hudson's Bay Territories* (BELL) [595], 690.
*Mining Compass and Trigonometer* (GAERTNER) [594], 870.

Mining in Mexico, 34.
Mining law in Nova Scotia, 686.
Minnie silver-mine, Leadville, Col. [181], 187.
*Mitis-Castings of Wrought-Iron or Steel* (OSTBERG) [595], 773.
MOEN, PHILIP W., *Biographical Notice of Professor Charles O. Thompson* [13], 190.
Moisic Iron-mines, Province of Quebec, Canada, 520.
Molybdenum in Hudson's Bay territories, 693.
Monongahela coal-measures, Pa., 637.
Montagu gold district, Halifax County, Nova Scotia, 322, 681, 689.
Montgomery County, Virginia, Silver and gold deposits in, 83.
Montreal Iron-works, Canada, 523.
Mooer's Forks, Clinton County, N. Y., fire-sand, 758.
Moose River, Hudson's Bay territories, Canada, gypsum, 694.
Moose River iron-works, Nova Scotia, Canada, 537.
Moose River, Nova Scotia, gold [679], 683.
Morgan County, Tenn., coal [295], 297.
Morning Star silver-mine, Leadville, Col., 287.
Morrisdale coal-mine, Clearfield County, Pa., 27.
Moshannon Creek coal-bed, Pa., 34.
Mountain sandstone, Pa., 647.
Mount Cory silver-mill (lixiviating), Nev., 497 *et seq.*
Mount Nebo, Pa., oil-pool [425].
Mount Pleasant iron-mine, N. J. [909].
Mount Savage, Md., Manufacture of fire-brick at, 698.
Mount Uniacke, Nova Scotia, gold, 682, 689.
Moyer silver-mine, Leadville, Col. [182, 186], 188, 288.
Muertos gold-mine, Vera Cruz, Mexico, 336.
Murphy coal-mine, Clarion County, Pa., 29.
Murraysville gas-wells, Westmoreland County, Pa., 435 [437].

Nastapoka Islands, Hudson's Bay, Manganiferous epathic ironstone on, 692.
*Natural Gas* (METCALF), 589.
Natural gas, anticlinal theory of, 654; Explosions of, 669; Geology of, 428; In Pennsylvania, 620, 650, 667.
Nevil Bay, Canada, iron pyrites, 697.
New Albion gold-mine, Montagu, Nova Scotia, 681.
New Almaden, Cal., Quicksilver condensation at, 206.
New Brunswick, Canada, iron-manufacture, 535.
New Cumberland gas-wells, West Virginia [667].
New Discovery silver-mine, Leadville, Col. [276, 284], 289.
*New Fire-brick Hot-blast Stove* (STROBEL) [12], 159.
New Glasgow, Pictou County, Nova Scotia, clay-ironstone, 62; coal-mines, 408; Visit to, 323.
*New Method for the Determination of Phosphorus in Iron and Steel* (MACKINTOSH) [321], 385.
*New Method of Submarine Tunneling* (ROTHWELL) [594], 770.
*New Mining Code of Mexico* (CHISM) [13], 34.
New River coal-field, Tenn., 296.
Niagara Steel-works: Ontario, Canada, 534.
Nictaux blast-furnaces, Nova Scotia, Canada, 539.
No. 21 iron-mine, Port Henry, N. Y., 910.

Norfolk County, Ontario, Canada, Iron in, 532; Manufacture of iron in, 524.
Normandale, Ontario, Canada, Manufacture of iron at, 524.
North-East Cape, Canada, Gypsum at, 694.
Northeastern steel-works, England, 463 *et seq.*
North Saskatchewan River, Canada, Gold in, 694.
Nottingham Island, Canada, Red granite on, 697.
*Note on a Deposit of Fire Sand in Clinton County, N. Y.* (BRAINERD) [595], 757.
*Note on an Exhibition of Banded Structure in a Gold Vein* (ROLKER), 265.
*Note on a Self-Dumping Water-Tank* (PIERCE) [319], 371.
*Note on the Apatite Region of Canada* (HUNT) [319], 495.
*Note on the Contraction of Iron on Sudden Cooling* (HOWE) [329], 400.
*Note on the Determination of Small Quantities of Titanium in Iron or Steel* (WELLS) [595], 763.
*Note on the Reduction of Ferric Solutions by the Use of Amalgamated Zinc and Platinum Foil* (BEEBE) [595], 766.
*Notes on Certain Iron-Ore Deposits in Colorado* (ROLKER) [13], 266; Correction, 950.
*Notes on the Constitution of Cast-Iron* (DUDLEY and PEASE) [594], 795.
*Notes on the Leadville Ore-Deposits* (ROLKER) [13], 273; Correction, 950.
Nova Scotia: Excursions in, 322; Iron manufacture in, 54, 537; Geology of gold-field, 676; Product of gold, 688, 689.
*Nova Scotia Gold Mines* (GILPIN) [595], 674.

O'Hara Glass Works, Pittsburgh, Pa., 603.
Oil-pools: *New York:* Allegany County, Richburg, 420; Cattaraugus County, 420; Rochester [651]; *Pennsylvania:* Beaver District, Slippery Rock, 424, 431; Smith's Ferry, 424, 431; Butler County, 424 [425], 431; Chartier's Creek, Washington, 431; Clarion County, 424 [425], 431; Fayette County [425]; Dunlap Creek [425], 431; Forest County, 420, 422, 651; Green County, Dunkard Creek [425], 431, 620, 642; Whiteley Creek [425], 431; McKean County, Bradford, 420 [425], 433; Smiethport, 427; Mt. Nebo [425]; Thorn Creek, 431; Venango County, 422, 424, 431; Franklin, 422; Pleasantville [425]; Warren County, 420; Cherry Grove, 422; Tidioute, 422; Triumph, 422; Westmoreland County [425], 431; Pleasant Unity [425], 431.
Oil-regions of Pennsylvania and New York, 419.
Oil-sand group, Pa., 648.
Oil-wells see (Oil-pools.)
Oker, Germany, Copper-works at, 98 *et seq.*
Old Bed iron-mine, Port Henry, N. Y.
Oldham gold district, Nova Scotia [679], 689.
Old Moshannon coal-mine, Clearfield County, Pa., 27.
Oliver Brothers & Phillips's steel works (Clapp-Griffiths), Pittsburgh, Pa., 919.
OLIVER, HENRY W., JR., Remarks on Clapp-Griffiths Process, 927, 936.
Omega silver-mill, Virginia City, Nevada, 756.
Ontario, Canada, Early attempts to manufacture iron in, 523.
Ontario silver-mill, Utah [341].
*Operation of Warwick Furnace, Pa., from August 27, 1880, to September 1, 1885* (BIRKINBINE) [595], 833.
Ore-crushing machinery, Improvements in, 497.
Ore Knob, Ashe County, N. C., Iron and copper sulphides in, 81.
Ormsby blast-furnace, England, Work of, 368.

Östberg, Petter, *Mitis-Castings of Wrought-Iron or Steel* [595], 773.
Ottawa Islands, Hudson's Bay, Canada, asbestos, 697; gypsum, 694; copper pyrites, 692.
Ottawa Iron and Steel Manufacturing Company, Canada [522].

Pacer Station, Costilla County, Col., magnetites, 271.
Pandora silver-mine, Leadville, Colorado [275].
Pantall coal-mine, Jefferson County, Pa., 28.
Panuco copper-mine, Coahuila, Mexico, 196.
Panuco gold-mine, Coahuila, Mexico, 202.
Papers: Of Chattanooga, Tenn., meeting, 17; Halifax, Nova Scotia, meeting, 325; Pittsburgh, Pa., meeting, 607.
Park, Bro. & Co.'s steel works, Pittsburgh, Pa., Visit to, 603.
Parker, W., Views of, on steel boiler-plates, 827.
Partridge Lake, Canada, Gold at, 693.
Patton coal-mine, Jefferson County, Pa., 28.
Pay-streaks in Nova Scotia gold-mines, 682.
Peace River, Canada, gypsum, 694; petroleum, 696; silver, 693.
Pease, F. N. (and C. B. Dudley), *Notes on the Constitution of Cast-Iron* [594], 795.
*Peculiar Phenomena in the Heating of Open-Hearth and Bessemer Steel* (Garrett) [594], 789.
Penn coal mine, Clearfield County, Pa., 27.
Petroleum in Hudson's Bay territories, 696; in Lower Devonian Rocks of Pa. and N. Y., 651. (See also Oil-pools).
Phœnix iron-mine, Boyertown, Pa., 895.
Phosphate-rock, Analysis of, 83.
Phosphide of iron in cast-iron, 799.
Phosphorus, Estimation of in iron and steel, 377, 382, 385.
*Pictou Coal-Field* (Poole) [319], 403.
Pictou coal-field, Nova Scotia, Excursion to [323].
Pictou County, Nova Scotia, bituminous coal, 63; clay-ironstone, 62; coke, 317; iron, 54, 538; limestone, 63; steel-works, 542.
Pierce, W. Ide, *Note on a Self-Dumping Water-Tank* [319], 371.
Pig-iron manufacture in Pennsylvania, 658, 659; South of Pennsylvania and Ohio, 5.
Pine Run gas-well, Westmoreland County, Pa., 435.
*Pittsburgh and Vicinity* (Shinn) [589], 657.
Pittsburgh Barren Coal Measures, Pa., 640.
Pittsburgh coal-region, Geology of, 618, 629.
Pittsburgh, Pa., Isabella furnace, 861.
Pittsburgh, Pa., meeting, Proceedings of, 587; papers of, 607.
Pittsburgh Plate Glass Works, Visit to, 602.
Pittsburgh Steel Casting Works, Visit to, 604.
Pleasant Unity, Westmoreland County, Pa., oil-pools [425], 431.
Pleasantville oil-pool, Venango County, Pa. [425].
Pocono sandstone, Pa. [647].
Poole H. S., *Pictou Coal-Field* [319], 403.
Poplar Creek, Anderson County, Tenn., coal (293, 294).
Port Henry, N. Y., Clapp-Griffiths steel works [922].
Portland rolling-mill, New Brunswick, Canada, 537.
Portland Township, Canada, apatite, 495.

Potter County, Pa., coal, 33.
Pottstown, Pa., Warwick blast-furnace, 833.
Pottsville conglomerate, Pa., 645.
POWELL, W. H., Remarks on Clapp-Griffiths Process, 928.
*Present Value of Steel Castings* (ABBOTT) [319], 351.
Proceedings: Chattanooga, Tenn., meeting, 1; Halifax, Nova Scotia, meeting, 307; Pittsburgh, Pa., meeting, 587.
*Process Used at the Comstock for Refining Coppery Bullion from the Amalgamation of Tailings* (HODGES) [595], 731.
*Product and Exhaustion of the Oil-Regions of Pennsylvania and New York* (ASHBURNER) [320], 419.
*Product of Iron-Ore at Hibernia Mines, N. J.* (PULLMAN) [595], 904.
*Professional Ethics* (BAYLES) [589], 609.
*Proposed Apparatus for Determining the Heating Power of Different Fuels* (KENT) [595], 727.
Pueblo, Col., kidney iron-ores, 270.
PULLMAN, J. WESLEY, *The Product of Iron-Ore at Hibernia Mines, N. J.* [595], 904.
Pyrites, roasted, Analyses of, 99 *et seq.*

Quebec, Canada, iron manufacture, 508.
Quebec steel-works, Canada, 521.
*Quicksilver Condensation at New Almaden* (CHRISTY) [13], 206.

Radnor iron-mines, Province of Quebec, Canada, 518.
Rainy River, Canada, lignite, 695.
Rat Portage, Canada, asbestos, 697.
Rat River, Canada, gold, 693.
RAYMOND, R. W., *Biographical Notice of Oswald J. Heinrich* [593], 784; *The Improved Brückner Cylinders* [320], 576; Remarks on the Clapp-Griffiths Process, 931, 937.
*Recent Failures of Steel Boiler-Plates* (KENT) [594], 812.
Redstone coal-bed, Fayette County, Pa. [637].
Red Lake, Canada, Soapstone at, 695.
Red Mountain, Alabama, Fossil ore in, 8.
*Relative Value of Coals to the Consumer* (CHANCE) [13], 19.
Robert E. Lee silver-mine, Leadville, Colorado [288].
Relief-maps, Methods of making, 441, 443.
Renfrew gold-district, Nova Scotia, 689.
Repulse Bay, Canada, Gold at, 693.
Reserve coal-mine, Cape Breton, Nova Scotia, 554, 557, 558.
Reynolds coal-mine, Jefferson County, Pa., 28.
Rhine steel-works, Germany, 463 *et seq.*
Richards iron-mine, N. J. [909].
Richburg oil-pool, Allegany County, New York, 420.
Richmond Gulf, Canada, lead, 692; silver, 693.
Ridgway gas-well, Elk County, Pa., 435.
Ringwood Furnace, Ringwood, N. J. [905].
Rising Fawn iron-mine, Georgia [79].
Rivet-steel, Specifications for, 832.
Roane Iron Company, Visit to furnaces and mines of, 15.
Roaring Run gas-well, Westmoreland County, Pa., 435.

Roberts silver-mine, Leadville, Colorado [284, 289], 291.
Rochester oil-well, N. Y. [651].
Rock silver-mine, Leadville, Colorado [182, 283].
Rockwood, Roane County, Tennessee, coal [294]; Excursion to, 15; Iron-mines [79].
Rohrer iron-mine, Roanoke County, Virginia [79].
ROLKER, CHARLES M., *Note on an Exhibition of Banded Structure in a Gold Vein*, 265; *Notes on Certain Iron-Ore Deposits in Colorado* [13], 266 (see correction, 950); *Notes on the Leadville Ore-Deposits* [13], 273 (see correction, 950.)
ROTHWELL, R. P., *A New Method of Submarine Tunneling* [594], 770; Remarks on the use of arsenic as a destroyer of injurious insects, 496.
ROUTLEDGE, W., *The Cape Breton Coal-Field* [319], 542.

Safety-Lamp, Wolf Benzine-Burning, 410.
Saguache County, Colorado, hematite, 268.
SALOM, PEDRO G., *The Manufacture of Steel Castings* [12], 118; Remarks on the Clapp-Griffiths process, 145.
Salt in Hudson's Bay territories, 694.
Salt River, Canada, gypsum, 694.
Salt-works at Goderich, Canada [788].
*Sampling of Cast-Iron Borings* (SHIMER) [595], 760.
Sanford iron-ore, Lake Champlain, N. Y. [811].
Scheibler's process for manufacturing magnesia, 458.
SCHMITZ, E. J., *The Wolf Benzine-Burning Safety-Lamp* [320], 410.
Schooner Pond coal-mine, Cape Breton, Nova Scotia, 553, 557, 558.
Schuylkill County, Pa., Mauch Chunk red shale in, 633, 646.
Scott County, Tennessee, coal [295].
Scottie Island, Lake of the Woods, Canada, iron-pyrites, 697.
Seley coal-mine, Jefferson County, Pa., 28.
Sequachee Valley, Tennessee, Geology and mineral resources of, 172; Coal in, 177.
Sewanee coal-seam, Cumberland Mountain, Tennessee, 178 [294], 305.
Sewickley coal-bed, Pa. [637].
Sharon coal-bed, Mercer County, Pa. [24].
Sharp coal-mine, Jefferson County, Pa., 28.
Sheffield gas-well, Warren County, Pa., 433, 436.
Sheffield oil-pool, Warren and Forest counties, Pa., 422.
Sherbrooke gold district, Nova Scotia [679], 682, 685, 689.
Shiesley coal-mine, Jefferson County, Pa., 28
SHIMER, PORTER W., *The Sampling of Cast-Iron Borings* [595], 760.
SHINN, W. P., *Pittsburgh and Vicinity* [589], 657.
Shoenberger blast-furnaces, Allegheny County, Pa., 658.
Silicon, Influence of, in steel-castings, 126.
Silver Cord silver-mine, Leadville, Colorado, 187.
Silver: In Montgomery County, Virginia, 83; Lixiviation of, in Mansfield, Germany, 747; Longmaid and Claudet processes for its extraction from roasted pyrites, 98.
Silver-mills: *Montana:* Butte, Lexington [343]; *Nevada:* Bertrand, 497 *et seq.;* Dayton, Lyon, 731; Galena, 501; Mt. Cory, 497 *et seq.;* Virginia City, Omega, 756; *Utah:* Ontario [341].
SILVER-MINES OF THE UNITED STATES: *Arizona:* Charleston, Knoxville [398]; *Colorado:* Leadville: Amie [288]; A. Y. [188]; Big Pittsburgh [288];

Chrysolite, 276 *et seq.*; Climax [288]; Col. Sellers [181], 187, 288; Crown-point, 189; Dome [182, 188]; Dunkin [284]; Evening Star [284], 287; Halfway House [284]; H. D. [186]; Hibernia [288]; Iron Silver, 287; La Plata, 189; Lime [188], 283; Little Chief [276], 286 [288, 289]; Little Pittsburgh, 286 [288, 289]; Matchless [288]; Minnie [181], 187; Morning Star, 287; Moyer [182, 186], 188, 288; New Discovery [276, 284], 289; Pandora [275]; Robert E. Lee [288]; Rock [182, 283]; Silver Cord, 187; Silver Wave, 283, 287; Smuggler [188], 283; Stone [182, 186, 188, 283]; Vulture, 289, 291; William Reddick [186]; *Nevada:* Comstock, 731; MEXICO: Zacatecas, Sombrerete [395].

Silver-ore in Hudson's Bay territories, 693.

Silver-ore, Analyses of, 189, 288, 395, 396, 399.

Silver Wave silver-mine, Leadville, Colorado, 283, 287.

*Simple Apparatus for Testing the Comparative Strength of Explosives* (WHINERY) [12], 75.

Sligo Furnace, Missouri [929].

Slippery Rock oil-pool, Beaver District, Pennsylvania, 424, 431.

Smelting-works at Freiberg, Saxony, [579].

Smethport oil-pool, McKean County, Pa., 427.

Smith's Ferry oil-pool, Beaver District, Pa., 424, 431.

Smithville iron-mine, Chaffee County, Col., 271.

Smuggler silver-mine, Leadville, Col. [188], 283.

Smullen coal-mine, Clarion County, Pa., 29.

Soapstone in Hudson's Bay territories, 695.

Soddy, Hamilton County, Tennessee, coal [294].

*Soft Steel for Boiler-Plates* (HUNT) [594], 826.

Soho blast-furnace, Allegheny County, Pa., 658.

Sombrerete silver-mines, Zacatecas, Mexico [895].

Songer coal-mine, Clarion County, Pa., 30.

Souris River, Manitoba, Lignite on, 695.

South Iron Hill, Leadville, Col., Sulphide deposits of, 181.

South Mountain, Pa., Geology of, 449.

South Pittsburgh, Visit to Tennessee Coal and Iron Company's furnaces, 15.

South Saskatchewan River, Canada, Petroleum on, 696.

South Staffordshire steel-works, England, 464.

Spang Steel and Iron Company, Pittsburgh, Pa., 926.

*Specific Gravity of Low-Carbon Steels* (MILLER) [320], 583.

Sprague coal-mine, Jefferson County, Pa., 28.

Spring Hill coal-mines, Cumberland County, Nova Scotia, 317; Visit to [323].

Springville iron-mine, Pictou County, Nova Scotia, 59, 60.

St. Croix plaster-quarries, Nova Scotia, Visit to [323].

St. Francis River, blast-furnace, Province of Quebec, Canada, 520.

St. George coal-mine, Nova Scotia, Canada, 541.

St. Mary's coal-mine, Elk County, Pa., 30.

St. Maurice iron-mines, Province of Quebec, Canada, 508.

Stack iron-mines, Allegheny County, Virginia [79].

Steel: Analyses of, 140, 141, 143, 144, 815, 932; Determination of quality by the fracture, 792; Determination of titanium, 763; Estimation of manganese, carbon, and phosphorus, 372 *et seq.*, 382; Homogeneity of open-hearth steel, 358; Influence of temperature in steel-making on the behavior of the ingots in rolling, 84; Manufacture of steel in Clapp-Griffiths converter, 919; of steel-castings,

118; Mitis-castings from wrought-iron or steel, 773; Overheating of steel not injurious, 794; Phenomena in heating open-hearth and Bessemer, 789; Physical and chemical properties of steel, 126; Soft steel for boiler-plates, 826; Specifications for rivet-steel, 832; Specific gravity of low-carbon steel, 583; Tests of steel, 359, 360, 361; Unequal cooling of ingots, 824.

Steel boiler-plates, recent failures of, 812; Specifications for, 830; Physical tests of, 814, 826.

Steel castings, Manufacture of, 118; List of ten American manufacturers of, 352; Present value of, 351.

Steel-works (Clapp-Griffiths): *Illinois*, Belleville, Western Nail Company, 922, 925; *New York*, Port Henry [922]; *Pennsylvania*, Birdsboro, E. & G. Brooke Iron Company [922]; Harrisburg, McCormick [922]; Lebanon, Lickdale [922]; Pittsburgh, Oliver Brothers and Phillips, 919; Pottstown, Glasgow Iron Company, 920.

Steel-works in Allegheny County, Pa., 662 *et seq.*

Steel-works in other countries: *Belgium*, Angleur, 488; *Canada*, Nova Scotia, Trenton, 542; Ontario, London, 535; Niagara, 534; Quebec, 521; *England*, Northeastern, 463 *et seq.*; South Staffordshire, 464; *Germany*, Rhine, 463 *et seq.*; *Russia*, St. Petersburg, Alexandrowsky, 464.

Stellarton, Pictou County, Nova Scotia, visit to, 323.

STETEFELDT, CHARLES A., *The Amalgamation of Gold-Ores, and the Loss of Gold in Chloridizing-Roasting, with Especial Reference to Roasting in a Stetefeldt Furnace* [319], 336.

Stirling coal-mine, Clearfield County, Pa., 27.

Stockholm, Sweden, Östberg's Mitis-foundry in, 779.

Stone silver-mine, Leadville, Col. [182, 186, 188, 283].

Stormont gold-district, Nova Scotia, 689.

*Straight or No-Bosh Blast-Furnace* (TAYLOR) [13], 88.

STROBEL, VICTOR O., *A New Fire-Brick Hot-Blast Stove* [12], 159.

Strouse's coal-mine, Jefferson County, Pa., 28.

Submarine tunneling, 770.

*Sulphide-Deposits of South Iron Hill, Leadville* (FREELAND) [13], 181.

Sutherland's River, Pictou County, Nova Scotia, spathic iron-ore, 60.

Swan River, Canada, Lignite on, 695.

Sydney coal-field, Cape Breton, Nova Scotia, 317, 323, 544 *et seq.*

Tangier gold-district, Nova Scotia [679]; Alluvial gold, 683, 689.

Tarentum gas-wells, Allegheny County, Pa. [437].

Tarentum, Pa., Visit to Philadelphia gas-works, 603.

TAYLOR, W. J., *The Straight or No-Bosh Blast-Furnace* [13], 88; Remarks on operation of Warwick Furnace, Pa., 861.

Templeton township, Canada, Apatite in, 495.

Tennessee Coal and Iron Company, Visit to furnaces of, 15.

Tennessee Upper Measure coal-field of, 292.

Thompson, Charles O., Biographical notice of, 190.

Thorn Creek oil-pool, Pa., 431.

Thurlow, Pa., Standard Steel Casting Co., 122.

Tidioute oil-pool, Warren County, Pa., 422.

Tipton Run, near Altoona, Pa., coal-beds, 632.

Titaniferous iron-ore in Nova Scotia, 537.

Titanium in irons and steels, 763.

*Topographical Models; Their Construction and Uses* (LEHMAN) [319], 439.
Toronto Iron-works, Ontario, Canada, 532.
Tracy City, Grundy County, Tennessee, coal, 177 [294].
*Treatment of Roasted Pyrites by the Longmaid and Claudet Processes for the Extraction of Gold and Silver* (EGLESTON) [13], 98.
Trenton Forge and Steel works, Nova Scotia, Canada, 542.
Trigonometer, 872.
Triumph oil-pool, Warren County, Pa., 422.
Trout Lake, Canada, Apatite on, 697.
Troy Steel and Iron works, Heine safety-boilers at [947].
Trumbull County, Ohio, coal-beds, 625.
Tudor iron-works, East St. Louis, Ill., 947.
Turner, Thomas, Views on steel boiler-plates, 828.

Underwood iron-mine, York County, Pa., 895.
Uniacke gold district, Nova Scotia, 689.
Uniontown coal-bed, Fayette County, Pa. [637], 639.
Uniontown, Fayette County, Pa., Iron-ore at, 646.
*Upper Measure Coal-fields of Tennessee* (COLTON) [12], 292.
Upper Barren coal-measures, Pa., 634.
*Use of Gasoline Gas in a Chemical Laboratory* (WAIT) [595], 769.
Utah, Southern, Iron-ore deposits of, 809.
*Utilization of the Copper and Iron Sulphides of Virginia, North Carolina, and Tennessee* (BOYD) [12], 81.

Vale coal-mines, New Glasgow, Nova Scotia, 405, 408.
Venango County, Pa., coal, 33; oil-pools, 422, 424, 431; oil-sands, 647, 648.
Vera Cruz, Mexico, gold, 336.
Victoria coal-mine, Cape Breton, Nova Scotia, 543, 550, 557, 558.
Virginia, Coprolites of [83].
Vulture silver-mine, Leadville, Col., 289, 291.

Wachob coal-mines, Jefferson County, Pa., 28.
Wagon Creek, Costilla County, Col., magnetites, 271.
WAIT, PROF. CHARLES E., *A Cupel-machine* [595], 767; *The Use of Gasoline Gas in a Chemical Laboratory* [595], 769.
Walnut Mountain coal-field, Tenn., 296.
Warren County, Pa., coal, 33; mountain sands, 648, 651; oil-pools, 420.
Warwick blast-furnace, Pottstown, Pa., 833.
Warwick iron-mine, Boyerton, Pa., 895.
Washington coal-bed, Pittsburgh, Pa., 626.
Washington County, Pa., coal, 634; natural gas [437]; oil-wells [647].
Washington oil-pool, Chartier's Creek, Pa., 431.
Water-tank, Note on a self-dumping, 371.
Watson iron-mine, Pictou County, Nova Scotia, 57.
Waverley gold-fields, Nova Scotia [679], 689; alluvial gold, 683.
Waynesburgh coal-bed, Greene County, Pa., 637.
Weaver iron-mine, Pictou County, Nova Scotia, 57.
Webster coal-mine, Clearfield County, Pa., 27.
Webster iron-mine, Pictou County, Nova Scotia, 58, 59.
Wellington copper-mine, Ontario, Canada, 692.

WELLS, HORACE L., *Note on the Determination of Small Quantities of Titanium in Iron or Steel* [595], 763.
Western Nail Company, Belleville, Ill., 922, 925.
Westinghouse gas-well, Pittsburgh, Pa., 668.
Westmoreland County, Pa., coal, 636; natural gas, 435 [437]; oil-pools [425], 431.
Westville, Nova Scotia, Acadia coal-pit, 407.
Wheatfield iron-mine, Berks County, Pa. [879], 895.
WHINERY, S., *A Simple Apparatus for Testing the Comparative Strength of Explosives* [12], 75.
White Mud River, Canada, Salt at, 695.
Whiteley Creek, Greene County, Pa., oil-pools [425], 431.
Whitwell, Cocke County, Tenn., coal, 177.
Whitwell-Cowper stove, 159.
Wilcox gas-wells, Elk County, Pa., 436.
Wilkins coal-mine, Clarion County, Pa., 29.
William Reddick silver-mine, Leadville, Col. [186].
Williamson coal-mine, Philipsburg, Pa., 30.
Wilton iron-mine, Middlesex County, Va. [79]
Windsor, Hants County, Nova Scotia, Visit to [323].
Wingert coal-mine, Jefferson County, Pa., 28.
WITHEROW, J. P., *The Clapp-Griffiths Converter: Later Practice and Commercial Results* [594], 919.
*Wolf Benzine-burning Safety-lamp* (SCHMITZ) [320], 410.
Woodstock, New Brunswick, Canada, iron ore, 535.
*Work of the Blast-furnaces of the North Chicago Rolling-Mill Company* (GORDON) [320], 362.
Wrought-iron (see Iron).
Wythe lead-mines, Austinville, Wythe County, Va. [787].

Yamaska County, Quebec, Canada, iron, 520.
Yankee Hill, Leadville, Colorado, Geology of, 280.
Youkon River, Canada, gold, 693.

Zinc and platinum amalgamation for reducing ferric solutions, 766.
Zinc in Hudson's Bay territories, 693.

AMERICAN INSTITUTE OF MINING ENGINEERS
ORGANIZED
1871

American Institute of Mining Engineers

Transactions

vol. 14, 1885-86

DATE DUE | BORROWER'S NAME